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Norway as Europe's Green Battery: Analysing Functions in Technological Innovation Systems for Renewable Energy Technologies

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The responsibility for inaccuracies or shortcomings in this thesis is completely mine.

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Abstract

In order to prevent global warming, the world is in need of a reduction in CO_2 emissions. This thesis seeks to analyse the possibilities Norway has to contribute to the reduction of greenhouse gases in its energy system. More specifically, it investigates the Norwegian technological innovation system for renewable energy technologies. Hampering factors to the development of renewable energy technologies are identified. These can assist decision-makers to design targeted, technology-specific policies. These hampering factors are explained in the context of the Norwegian national innovation system. This thesis claims that Norway appears to lack incentives in the development of renewable energy due to Norway's characteristic energy, economic and industry structure. Furthermore, Norway has been suggested as a part of the solution in the transformation of the European electricity sector. This thesis argues that an increased interconnecting capacity between Norway and Europe is feasible. However, there are still unanswered questions regarding the extent of such a development. The most prominent of these questions relates to the issue of legitimacy connected to price effects and nature interventions. Further research is needed, particularly on what effect an extensive development of interconnecting cables will have on the price of electrical power in Norway.

Contents

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1. Introduction

Renewable energy accounts for only 2.1% of the world's total energy consumption (BP, 2012). Consequently, 97.9% of all energy consumption stems from *non-renewable* sources of energy. The energy sector is the main contributor to greenhouse gas emissions, accounting for approximately 65% of human greenhouse gas emissions (IPCC, 2007). This sector includes subsectors such as energy supply, transport, buildings and industry. Scientists have stated that greenhouse gas emissions must be halved by 2050, compared to 1990 levels, in order to stabilise global warming below two degrees (ETH Zürich, 2009). To achieve this goal, in less than thirty-eight years from now, an extensive conversion of how we produce and use energy is needed.

A transformation of the energy sector at this scale is a political goal for many nations. This thesis will concentrate on Norway's potential role in the European contribution to reduce carbon emissions globally. Europe is gearing up in the fight against climate change. The European Union has released ambitious goals for reducing its carbon emissions, and goals for transforming the electricity sector have been announced (Directive 2009/28/EC; EU 2050). Specific and ambitious goals to decrease emissions of greenhouse gases are made. The first goal, the so called "20-20-20"–targets, is designed to reduce carbon emissions by 2020. This is formulated as follows: "A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels; 20% of EU energy consumption to come from renewable resources; A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency" (European Commission, 2010). This has resulted in the directive "Promotion of the use of energy from renewable sources" (Directive 2009/28/EC).

Furthermore, roadmaps exist for a more long-term perspective. These roadmaps seek to outline different goals and how to design appropriate policies on renewable energy towards the year 2050. The EU 2050 energy roadmap released by the European commission in December 2011 has outlined the possibilities for the European electricity sector to consist of 80% renewable energy by 2050. In addition, scenarios have been presented where the electricity sector is totally decarbonised by 2050 (EU 2050). In several of these, Norway has been suggested as a contributor to the European transformation with its abundant hydro power capacity.

A transition from an energy sector based on fossil fuels to a carbon-neutral energy sector will require significant upheavals in the industry and economic structure. To achieve a transformation to a sustainable energy sector, all production of electricity from fossil resources must be phased out and replaced by renewable energy sources. In Europe this means that 91% of all energy consumption must be replaced (Eurostat, 2009). Such an extensive transformation requires political will to overcome barriers and path dependencies. It is argued that neoclassical approaches such as market failures are not enough to overcome these (Jacobsson & Bergek, 2011; Lundvall & Borrås, 2005). Rather, technology-specific policies and innovation system analysis should be applied in order to obtain a more complete picture. For decision-makers to construct appropriate technology-specific policies, they need to have information about the system encompassing a desirable technology. In order to provide policy-makers with this, Jacobsson and Bergek (2011) argue that innovation system analysis can be applied. The strengths of these analyses are that they can identify hampering and facilitating factors for the emergence of various technologies. Identifying system weaknesses will provide decision-makers with valuable information to design policies for renewable energy technology.

The overall aim of this thesis is to analyse the possibilities Norway has to contribute to the reduction of greenhouse gases in its energy system. More specifically, the purpose is to investigate the Norwegian technological innovation system for renewable energy technologies. This is done in order to identify factors driving or blocking the diffusion of renewable energy technologies in Norway.

The goal of the analysis is threefold. Two are motivated by a wish to contribute to the theoretical framework on innovation systems and one is motivated by providing policy-makers with insight to design appropriate climate and energy policies. First, the analysis seeks to provide the functional analysis outlined by Bergek et al. (2008) with an empirical example. Second, it strives to couple the characteristics of a national innovation system with an empirical TIS functional analysis, an interaction of TIS with higher system levels (cf. Jacobsson and Bergek. 2011, p 53). It follows that the historical development of the Norwegian NIS is an essential explanatory factor of how well the Norwegian TIS of renewable energy performs. Finally, this analysis is an attempt to identify system failures in the TIS of renewable energy technologies in Norway. Thus, the case study seeks to illuminate Norwegian characteristics and investigate a solution for better market conditions for renewable energy in Norway. Furthermore, the TIS–concept seeks to provide decision-makers with sufficient information to make the suitable policies for the development of a technology.

This thesis is structured as follows. Section 2 outlines an empirical background and context that explains the Norwegian energy system and presents the research questions. Section 3 describes the theoretical framework. Subsequently, section 4 explains the methodology applied in this thesis. Furthermore, section 5 and 6 are empirical sections which apply a National and Technological innovation system analysis of renewable energy in

Norway. These two sections seek to identify characteristics with the Norwegian development of renewable energy technologies and, furthermore, to apply the functional analysis in order to identify system failures. Section 7 discusses the implication the characteristics of the Norwegian NIS has on the development of renewable technologies, as well as the importance of grid development. Finally, section 8 concludes on the background of the research questions and findings, and outlines suggestions for further research.

2. Empirical background and context

This section will outline the characteristics of the Norwegian energy system. It will be argued that Norway does not have the same incentives as its European counterparts to transform its electricity sector. Furthermore, it will be shown that Norway lags behind in the development of renewable energy technologies. Moreover, the possibility of an exchange of electricity with foreign countries will be described. This can be regarded as Norway's potential role in Europe's transformation of its electricity system. Knowledge from interviews made with central actors in the Norwegian renewable energy technology system has been revised and used in the mapping of the energy structure.

2.1 The Norwegian energy system; abundant resources

The Norwegian energy sector is unique; not only is Norway self-sufficient with green electricity from hydro power plants, vast gas and oil resources exist along the Norwegian coast. This uniqueness implies that Norway has a green production of electricity; mainland Norway has close to 100% renewable electricity production, which stems almost exclusively from hydro power. This is a relatively cheap source of renewable energy. The developed hydro power capacity in Norway will be significant cheaper than new renewable energy sources (Hanson, J., Kasa, S., Wicken, O., 2011, p. 12).

Compared to other European countries, Norway does not have the same incentives to transform its electricity production. Aggregated targets, as the European 20-20-20 – target, are irrelevant for Norway, because it meets these targets by a wide margin. However, Norway has committed to participate with an increase in the total share of renewables from 61.1% to 67.5%[1] by 2020. This is Norway's participation in the European 20-20-20 goal. This increase in renewable energy will be provided through increased investments in renewable energy in mainland Norway, which is, as mentioned, nearly completely renewable. This implicates that no fossil energy sources will be replaced, but rather that the increase has to derive from additional renewable energy.[2] In order to achieve this, more investments in renewable energy must take place.

Despite Norway's easy access to electricity from renewable sources, Norwegian carbon emissions are at the same level as its European counterparts. See figure 1. This is due to the high activity in the offshore petroleum sector. The gas driven offshore platforms contributes the total CO_2 emitted in Norway. This explains the good results for the electricity sector, but the rather average score in total emissions.

[1] These numbers include the offshore sector. The offshore sector is currently unattached from the central grid, if this sector is to be electrified, an extensive development of grid capacity between mainland Norway and the offshore facilities must be constructed.

[2] Norway has the possibility to increase its share of renewables through replacing fossil sources of energy the other sectors. Most relevant would be to electrify the offshore sector or in the transport sector through an increase in the use of electrical cars. However, these solutions can be regarded as extensive transformations that need significant more technology development and investments to occur. In addition, the gas that is not used at the offshore facilities for power will be exported. The consequence is that the CO2-emissions will be emitted anyway, just in another country. These two possibilities will not be the main focus of this assignment.

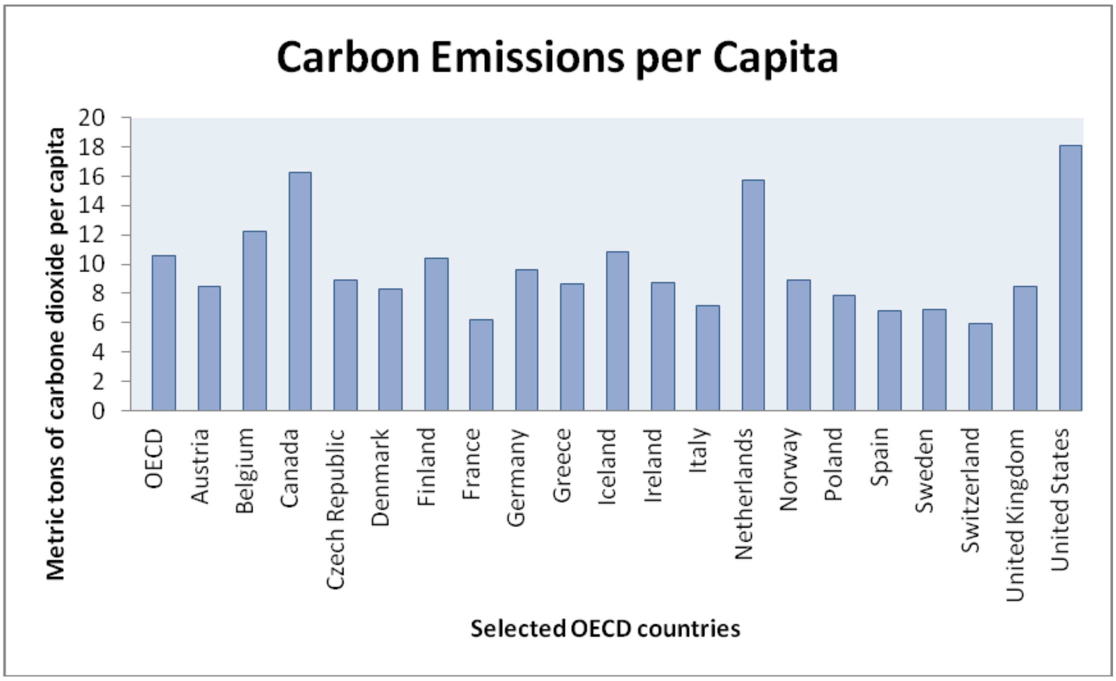

Figure 1. Carbon Emissions per Capita. Metric tons of carbon dioxide per capita in selected OECD countries, Norway scores average compared to European counterparts (Data retrieved form U.S. Energy Information Administration, 2010)

Furthermore, the petroleum sector accounts for 21 % of total Norwegian GDP, this is far more than any other industry in Norway (Norwegian Petroleum Directorate (NPD), 2011). Furthermore, to put the investments in the petroleum sector in perspective, the amount invested in the Norwegian shelf is more than ten times higher than in electricity production and infrastructure. In 2010 more than 130 billion NOK was invested in the petroleum sector (NDP, 2010), whereas investments in electricity production and infrastructure were 11.8 billion (SSB, 2012a). It is the second biggest exporter of natural gas (Central Intelligence Agency (CIA), 2010a) and the 6th biggest oil exporter in the world (CIA, 2010b). The oil and gas revenues provide Norway with a substantial capital income each year (Ministry of Finance, n.d. a).

The amount of wind power can be considered as an indicator of renewable energy development in Norway; compared to its European counterparts, it lags behind. Figure 2 illustrates this: a comparison of European countries' share of wind energy of total electricity production. Despite Norway's natural high potential for wind energy due to its long and windy coast, the development of wind energy has been slow. Compared to wind power pioneer countries such as Denmark, Spain and more recently Germany, there are significant differences. Norway's share of wind energy is 1%. This would have placed Norway between Luxembourg and Latvia in figure 2, positioned as number 21 out of 28 countries. There is, thus, a substantial improvement potential.

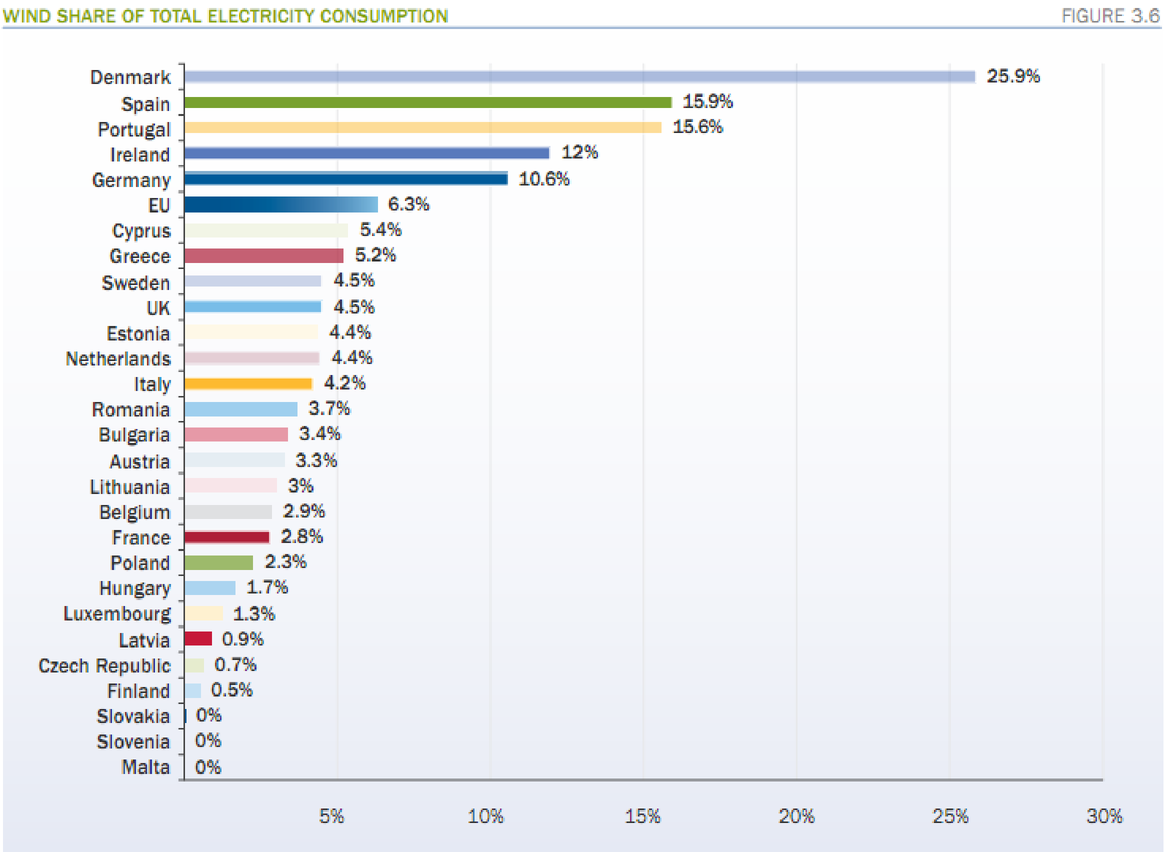

Figure 2. Wind power's share of total electricity consumption, Norway would place itself in between Latvia and Luxemburg with a share of about 1% (the European Wind Power Association, 2011)

One way to facilitate for, and accelerate, the development of renewable energy is to offer subsidies. Norway introduced the tradable green certificates scheme (TGC) to the energy market in 2012. This was done in collaboration with Sweden (which implemented TGC in 2003), so that the two countries formed a common market for green certificates. This is a tradable commodity, which will provide the production of renewable energy with subsidies. Germany started with its subsidy scheme, the feed-in tariff, in 1990. It can thus be argued that Norway has been slow in implementing subsidy schemes for renewable energy. Nevertheless, the green certificate scheme has a goal to develop 26.4 TWh in Norway and Sweden before 2020 (Ministry of Petroleum and Energy, 2012). It is believed that the green certificate market will be important for Norway to reach its goal of 67.5% share of renewable energy.

2.2 Power exchange with surrounding countries

The Norwegian electricity grid is not isolated from the European grid. There are interconnecting cables that enables an exchange of electricity with Europe. Currently, Norway possesses transmission capacity of approximately 5.5 GW for export and import with other countries (SNL, 2010). The main part of this capacity is the connection between Norway and Sweden, which has a capacity of between 3200-3600 MW. Furthermore, three cables that provide an exchange capacity of 1000 MW exist between Norway and Denmark. In 2008 the construction of a cable between Norway and the Netherlands was completed, enabling an exchange capacity of 700 MW between the two countries today. These cables have contributed to a partially common market for electricity in the northern countries, limited by the capacity in the electrical grid.

Norway has traditionally been an exporter of electricity (Hanson, J., Kasa, S., Wicken, O., 2011, p. 11), hence the interconnecting cables have been used for selling electricity on the common northern market for electricity. In recent years, however, Norway has increased its energy consumption without increasing the electricity production. This has led to a situation where Norway has been a net importer of electricity in several of the years since 2000 (Hafslund, 2012).Thus, the cables that connect Norway to Europe are, in years with a deficit in the electricity balance, important for the security of Norwegian power supply. An illustrative example is the dry winter of 2002/2003: the export cables were running on full power, nevertheless this was not enough to cover the demand for electricity. This resulted in a strong increase in electricity prices and in some parts of Norway to extreme prices (Store Norske Leksikon, 2010).

There are plans for significant national investments in both the national electrical grid and new interconnecting cables between Norway and the European electrical grid. This is a result of expected new investments in renewable energy because of the introduction of green certificates in the Norwegian market, as well as the need for exchange of electricity between Norway and surrounding countries to maintain security of power supply. Between 40 – 45 billion Norwegian kroner is expected to be invested in the Norwegian electrical grid over the next few years (S. V. Larsen, personal communication, May 25 2012). There is a need to strengthen the transmission capacity due to stronger fluctuations between night and day and between different seasons (Statnett, 2011). Furthermore, interconnectors between Norway and the continent will be built. By 2022 the Norwegian Transmission System Operator (TSO) Statnett will, if current plans are followed, double the interconnecting capacity to Europe. This means that the capacity will exceed 10 GW in 2022 (S. V. Larsen, personal communication, may 25 2012). Existing connectors are planned to be upgraded with higher capacity. In addition, interconnectors to countries that previously have had no direct interconnecting cables to Norway will be built. More precisely this involves that the link to

Sweden and Denmark will be strengthened with improved capacity. Furthermore, two new cables to currently unconnected countries are planned: one cable between the western part of Norway and England (which will be the longest high voltage cable in the world). Additionally a cable to Germany from the south of Norway is being planned. Both these new interconnectors will have a capacity of 1400 MW. See table 1.

Table 1

Power Exchange Capacity in Norway.

Country	Today's capacity	Planned capacity
Sweden	3200-3600 MW	1400 MW
Denmark	1000 MW	700 MW
Netherland	700 MW	0
Germany	0	1400 MW
Great Britain	0	1400 MW
Total	4900 – 5300 MW	4900 MW

Note: This table represents summary of current and planned capacity (in approximate numbers) of interconnecting cables between Norway and surrounding countries. (Sources: Statnett, 2012; SNL, 2011).

An increased net electrical grid capacity in Norway, both domestic and increased capacity in interconnectors with other countries, could yield many benefits. Explicitly these could be: i) contribute to a better distribution of produced electricity in the Norwegian domestic market for electricity; ii) yield a possibility for Norway to export excess electricity to the European market and consequently import excess energy from the European market; iii) it could provide Norway with a better security of electricity supply due to the possibility to import larger volume of electricity when the demand is high.

An increased interconnector capacity can contribute to higher efficiency in wind power plants in Europe. Due to Norway's easy access to flexible hydro power, it could gain trade benefits from importing when demand is low and exporting when demand is high. Wind energy plants do not have this flexibility; the wind speed does not always correlate with the demand. Hence, Norway can contribute to a higher efficiency in renewable energy facilities in Europe. For example, this could be done in wind power plants; excess and cheap electricity in the European market can be imported and the electricity production in Norwegian hydro power plants can be halted. Furthermore, Norway can gain on this in terms of trade profits, because of the fluctuations in the price for electricity.

2.3 Norway as Europe's green battery.

At the same time as Norway is struggling to justify more investments in renewable electricity, Germany, the highest consumer of electricity in Europe with a share of 19.2% (Eurostat, 2012), has announced the intention of a shutdown of all nuclear reactors by 2022. The share of nuclear energy in Germany has in the last decades been at around 30% (World Nuclear Association, 2012). Due to a shutdown of reactors in recent years this has declined to 17% in 2011. Consequently, for Germany to accomplish to shut down all reactors by 2022, 17% of the energy produced in Germany has to be replaced by an alternative source of energy over the next ten years (or emissions cut through energy savings). For Germany to fulfil its goals, both the "20-20-20" goal and a phase-out of nuclear power, it is in need of an extensive development of new renewable energy sources. This further increases the demand for development of renewable energy in Europe. This is in progress; there are increasing investments in both wind and solar energy facilities and the German government facilitates this with generous subsidies through their feed-in tariff system. Germany has increased the share of renewable energy in the gross electricity production from 3 % in 1990 to 20 % in 2011 (Bundesminesterium für Umwelt, Naturschutz und Reaktorsicherheit, 2012).

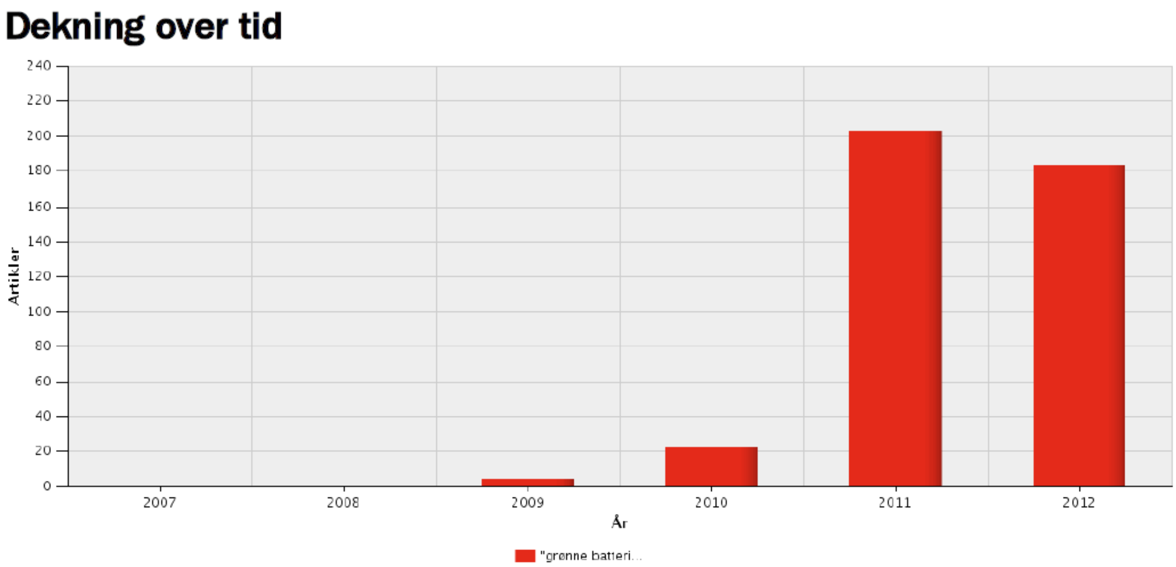

Figure 3. Number of times “green battery” has been mentioned in Norwegian newspapers from 2007 until august 2012 (Source: Metasearch in Retriever).

The notion of Norway as Europe’s green battery has received increased attention in recent years. A metasearch in the Norwegian media database “Retriever” gives the result seen in figure 3.The notion got no attention until 2009, before it exploded in 2011. In December 2010 Norway and 9 surrounding countries signed a ‘Memorandum of understanding’ in conjunction with “The North Sea Countries’ Offshore Grid Initiative” (regjeringen.no, 2010). At the same time suggestions on how to decarbonise the European electricity sector have been created. In various roadmaps made by different German institutions, Norway was presented with an important role in order to balance the European power grid. Norway has in these reports been suggested as the solution to the storage capacity challenges connected with renewable energy technologies. This has contributed to an increased interest in the green battery concept by Norwegian actors, and thus has led to more attention in Norwegian media.

In line with the development of wind energy in the area around the North Sea, there is a need for increased distribution and storage capacity of electricity. In 2011 the German Advisory Council on the Environment (SRU) published a study with different scenarios for a total decarbonisation of Germany by 2050: “Pathways towards a 100% renewable electricity system” (2011). In many of these scenarios, Norway is intended to play a role in balancing the electricity with its extensive hydro power capacity. Germany’s ambitions for Norway are comprehensive; up to 50 GW of transmission capacity is suggested. Compare the current amount of 5.5 GW capacity with foreign countries in total, this can be considered as a severe increase. In addition, some of the German reports have proposed that pump mechanisms should be constructed in Norwegian hydro power facilities. In that way Norway could buy cheap electricity from the European market to store it until the electricity demand increases. In order to carry out a development near this scale there is a need of considerable investments in the Norwegian national grid and hydro power plants. These are infrastructural investments that go far beyond current plans.

2.4 Research Questions

As has been outlined in this chapter, Norway trails behind in the development of renewable energy. Compared to European countries, the development of renewable energy technology has been scarce in recent years. Despite a significant potential in developing, for instance, wind power, not much has been carried out. Why does Norway trail behind? This leads us to the first research question of this thesis:

RQ1: What hampers the development of renewable energy in Norway?

The second research question in this thesis regards a situation where Norway connects to the European electricity market. An increased exchange of electricity between Norway and Europe will possibly release a potential for a more efficient and profitable operation of the Norwegian hydro power reservoirs. The development of wind energy plants in countries in northern Europe creates a demand for storing and providing energy when electricity production does not correlate with electricity demand. Hydro power is abundant in Norway. Hydro power plants have an advantage in renewable energy production because it is one of the only renewable energy sources that provides flexible electricity production. The thought is that Norway can import cheap electricity when the wind power plants produce more electricity than needed (e.g. during nights and summers), and temporarily halt hydro power production. This allows Norway to produce more electricity when demand and prices are high, consequently getting increased returns from its hydro power plants. However, this requires an extensive development of the Norwegian power grid, which includes both an upgrade of the domestic power grid, as well as new power cables between countries.

RQ2: Germany has proposed a solution where Norway is the “green battery of Europe”. Is an increased exchange of electricity between Norway and Europe feasible?

3. Theoretical framework

This section will present the theoretical concepts this thesis is based upon. First, the concepts of evolutionary economics and general innovation literature are briefly outlined.

Subsequently, the theories are narrowed down throughout the chapter until they reach the specific concepts this thesis seeks to illuminate. This is done in order to explain the innovation literature to readers that are not familiar with evolutionary economics. Without this background, the specific theories applied in this thesis would be insufficient for many readers. Furthermore, it is attempted to explain the motivation for choosing the evolutionary approach over neoclassical ("orthodox") economics when dealing with technology development.

This chapter is thus structured deductively. First, there is a broad description of evolutionary economics and innovation literature. Next, the systemic approach to innovation is outlined. Subsequently, two specific system approaches are described; national innovation system (NIS) and technological innovation systems (TIS). These innovation systems are chosen because they are applied in the analysis of this thesis. The national characteristics of Norway and characteristics in the technological innovation system (TIS) of renewable energy are highly relevant in order to answer the research questions. Finally, the scope of the analysis in this thesis is justified. Moreover, the importance of applying both the concept of NIS and the concept of TIS is explained. This last part will function as a bridge to the empirical chapter and to demonstrate the connection between theory and empirical findings in this thesis.

3.1 Evolutionary Economics and Innovation

"Everything is connected with everything" (Gro Harlem Brundtland).

The term evolutionary economics is meant as an analogy to the concept of evolution in biology. It is not directly transferable from biology to the study of socio-economics, but refers to a broader use of the term 'evolutionary' (Nelson, 1995, p. 54). Evolutionary economics emphasises that the economy is driven by selection mechanisms similar to what is found in biology, where the fittest idea or technology survives in the long run. One of the central ideas is that technological change influences economic development deeply; different technologies compete against each other and they shape the society. Consequently, technology development is something that should be emphasised, measured and understood. With this as a background, evolutionary economists seek to explain long-run economic change. Furthermore, they criticise traditional economic theory as it does not take these technological aspects into account when modelling an aggregate economy. Nelson & Winter use the term *orthodox* in their influential book "An Evolutionary Theory of Economic Change" (1982) about traditional economic theory that emphasises economic equilibrium models as a main concept. This thesis will use the term neoclassical economics about the mainstream alternative to evolutionary economics.

Neoclassical economists can be criticised for treating technological change as an exogenous variable in their models (Nelson & Winter, 1982, p.4). Exogenous variables are variables with values that are taken for granted; they are unexplained in the model and they are treated independently. Moreover, their values are determined from exogenous factors created outside of the model. Factors determined in the economic model can thus not influence an exogenous variable, and the economic model must simply adapt to the exogenous variables as they independently change. This has the implication that, in economic models, technology is an unexplained variable that seems simply to occur as a result of uncontrolled coincidences in society. Furthermore, Nelson and winter (1982) criticise the notions of profit maximising and equilibrium with the background in that technological change is a dynamic process (p. 30).

Whereas neoclassical economists treat technological change as an exogenous variable in their models, evolutionary economists emphasise that technological change is an *endogenous* variable. These variables are determined within the model and they are influenceable; hence they are responsive to economic and technological policies. There exists an ambition in evolutionary economics and innovation theory to open up the “black box” of economics; to explain the impact of technological change on the aggregate economy.

Moreover, scholars of evolutionary economics believe that technological development is a societal attribute that can be understood and influenced (cf. the systems of innovation and technological specific policies that will be described later). The key to this is to understand the mechanisms that lie behind the paths of technological change, along with analysing socio-technical systems that surround technologies. They seek to understand and analyse the complex societal dynamics behind technological development. Furthermore, they aim to influence and measure technological development, due to its allegedly strong impact on the economy. To do this it is desirable to generate increased information about innovation systems and consequently provide decision-makers with suggestions for technological policies. This way, the relation between policies for R&D investments and technological development and innovation can be analysed and understood.

Innovation

Innovation is a key concept in evolutionary economics theory; the innovation *process* is assumed to lie behind technological change. Innovation is thus, cited from Fagerberg (2005), “a powerful explanatory factor behind differences in economic performance between firms regions, and countries” (p. 20). The notion of innovation is closely linked to the notion of novelty, i.e. to do something in a novel way. From the origins of innovation theory the influential evolutionary economist Joseph Schumpeter defined innovation (or development as he initially phrased it) as: "“new combinations” of new or existing knowledge, equipment, and so on" (Schumpeter, 1934, p. 65). Another broad definition of innovation is to do something in a novel way, i.e. a better technical solution to a societal problem. Edquist (2005) defined innovation more specifically and divided innovation into two subcategories; product innovations and process innovations. As he writes: “Product innovations are new – or better – material goods as well as intangible services. Process innovations are new ways of producing goods and services. They may be technological or organizational.” (Edquist in Fagerberg et al., 2005, p. 182).

Despite the physical appearance of technologies, innovation, and consequently technological development, cannot be fully understood on the sole basis of natural science or engineering. It is difficult to explain the emergence of technologies without including various societal aspects, such as market conditions (supply and demand); political landscape; sociology of technology; design features; historical development paths; macro- and microeconomics; informatics etc. The study of innovation is thus an interdisciplinary study of society; it strives to explain technological and economic change with a diverse set of approaches and academic disciplines (Fagerberg, 2005, p. 3). Consequently, the range of disciplines is not limited to one specific type of science, but crosses and opens up the academic traditions, e.g. natural and social sciences; humanities; architecture and design; and engineering.

As well as an inter-disciplinary approach, the innovation approach to economics and technology development is a long-term approach. Innovation theory emphasises the long-term development of the economy and technology. This stands in contrast to neoclassical economics, which rarely has a desire to calculate any further than in the medium-term. The longer the terms are in economics, the more variable factors there will be in calculations.[3] It is often stated that in the long-term, all factors are variable (Bernheim & Winston, 2008, p. 216). Long-term socio-economic equations with many variables are not desired in economics, because they can be difficult to calculate accurately. Hence, the results will probably contain a high degree of uncertainty.

Innovation theory, however, seeks to explore this black box of economics. What drives long-term economic growth? Thus, the study of innovation is a study of framework conditions and input factors that are constantly changing. Technological change is considered a dynamic process with feedback mechanisms (Fagerberg, 2005, p. 13). Furthermore, innovation is believed to be the driving force of this progression. Hence, it is difficult to calculate innovation's societal influence mathematically.

In order to assess long-term economic growth, innovation researchers apply methods other than standard economic models. One of the most influential approaches in innovation theory has been to view the innovation process in a system perspective. The idea is based on the notion that the surroundings of a technology can be considered as a system. Fagerberg (2005) describes systems as "a set activities (or actors) that are interlinked" (p. 13). Applying the system concept to the study of innovation allows innovation researchers to describe the characteristics of an innovation system. This way it is possible to identify the factors that hamper or facilitate the development of a technology in an innovation system. This

[3] If the reader is familiar with economics: to solve a set of socio-economic equations, there has to be as many equations as variables. When the variables are many (as in the long-term), it demands a high accuracy of the equations that characterises the economic contexts. This accuracy is harder to obtain the more variables that exist, because it requires detailed knowledge of socio-economic relations.

information can be used by decision-makers to design appropriate policies. The reminder of this theoretical chapter will describe the innovation system approach.

3.3 Systems of Innovation

"[…]'innovation System' has won the approval of an increasing number of academic researchers interested in the processes underlying innovation, industrial transformation and economic growth.*"* (Bergek et al., 2008, p. 407).

The systemic view has been a central perspective in innovation literature. The systemic approach originates from Swedish innovation researcher Bengt-Åke Lundvall's article "Product innovation and User-Producer Interaction", which was written in 1985. The notion was further developed by Freeman with his "national system of innovation" (NIS) in 1987 (Edquist, 2005), where he connected NIS with the growth of the Japanese economy. The systems of innovations (SI) approach emphasises the factors that are essential in order to turn an idea into a concept or a product, i.e. the innovation process. Another Swedish innovation researcher, Charles Edquist (2005) defines innovation systems as: "all important economic, social, political, organisational, institutional, and other factors that influence the development, diffusion, and use of innovations" (p. 182). Innovation is thus a process that is influenced by a set of different factors. This is why the system approach is regarded as an appropriate approach to the study of technological progression.

One of the SI's main points is that an innovation is not a result of one firm's individual work, but rather an outcome of many actors working together. It is said to be a holistic and interdisciplinary perspective (Edquist, 2005, p. 185); it emphasises the importance of multi-disciplinary approaches in system thinking. In order for a technology to emerge and develop, it is dependent upon contributions from various actors and institutions, and these could be derived both from the private and the public sector. To study how innovations are being created, the systemic approach states that one should not view the firm or individual that develops the product or technology in isolation, but include all the contributors to the system that make the innovation possible. Hence, external artefacts are important for innovation (Fagerberg, 2005, p. 12), e.g. educational institutions, financial institutions, labour force, political feasibility and processes etc.

The system perspective seeks to explain what causes technology development and productivity within, for instance, a country. This is in contrast to neoclassical macroeconomics, which considers technological development and labour productivity as exogenous factors. The broad definition of SI has its strengths, in that it combines different actors of an innovation system together in the understanding of what an innovative process is. It is a non-linear process with feedback mechanisms, which leads to an evolution of the surrounding innovation system over time (Fagerberg, 2005, p. 13). The evolution of an SI emerges as a result of the interdependency of the different institutions and actors. Moreover, the evolution is affected by the level of experimentation with different processes and technological solutions.

The SI approach has been subject to criticism, and one of the most dominant is that the concept is in itself diffuse. Compared to traditional economic theories, it is less applicable, because there are no fixed rules on where the borders of the system should be drawn. In addition, there are no real definitions of which actors that should be included in the analysis. Hence this implies that there are no certain quantitative methods to measure the involved variables and the calculation of a model. For traditional economists this could thus be seen as a useless theory because of the lack of generalisation possibilities. It is important to stress that the notion of ‘systems of innovation’ is not meant as a theory, but rather an approach or a conceptual framework (Edquist, 1997, cited in Edquist, 2005, p.186). [4]

3.4 National Innovation Systems

“National innovation system is the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies” (Freeman, 1987, p. 1).

The national innovation system (NIS) is limited by national borders, and focuses on domestic factors that influence the level of technological and organisational development in both private and public sector. Relevant actors in NIS are characteristically enterprises, universities, government research institutes, politicians and policy makers. The approach has typically been applied to comparative studies between countries. There are for example different classifications of how well innovation is carried out in countries. Normally, different indicators of innovation are plotted against GDP per capita to observe correlations or deviations. This has shown a good potential among innovation researchers in showing the importance of innovation on nation’s GDP and standard of living. NIS has thus provided quantitative data in a field of research where quantitative methods can be argued to have been scarce.

The national approach to innovation systems has also been important for the Organisation for Economic Development and Co-operation, OECD, in order to compare productivity and innovation between member countries. OECD focuses on how knowledge and technology information is distributed throughout a nation. The organisation concentrates

[4] Minor parts of this text are based on previous assignments written by the author of this thesis. These have not been published.

on four measurement categories in particular: 1) interactions among enterprises; 2) interactions among enterprises, universities and public research institutions; 3) diffusion of knowledge and technology to enterprises; and 4) personnel mobility (OECD, 1997). These can be measured through innovation surveys, cluster analysis and more conventional technology indicators such as R&D expenditures and patent analysis. Hence, NIS is a strong tool for comparative analysis of factors behind innovation and innovation performance in countries.

The characteristics of a nation's innovation system are important for the performance of technology development. Hence, a country's distinctive industrial and political pattern can be used as explanatory factors for the diffusion of certain technologies. This is highly relevant for this thesis, because Norway's industrial pattern and political pattern can be said to differ significantly from its European counterparts. It is thus appealing to look into the Norwegian national innovation system in order to examine Norway's performance in the development of renewable energy technologies.

3.5 Technological Innovation Systems

"A technological innovation system is a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product" (Markard and Truffer , 2008, p. 611)

Technological innovation system (TIS) aims to explain the mechanisms behind the emergence of technologies in the society. A TIS is, as the name suggests, a systemic approach. Hence, it seeks to outline and determine which actors and institutions contribute to the innovation system that surrounds a certain technology. Contribution, in this context, refers both to what facilitates the technological field, and also which institutions and actors hamper the technological innovation process.

Jacobsson and Johnson (2000) write that not only market failures can block the evolution of a new technological innovation system, but also that there exists network and institutional failures. Network failures could be “Poor connectivity” or “Wrong guidance with respect to future markets”. Whereas they list institutional hampering factors such as: “legislative failures; failures in the educational system; skewed capital market; underdeveloped organisational and political power of new entrants.” (p. 631). Jacobsson and Johnson (2000) conclude that “the rate and direction of technological change – the process of technological choice – is decided in competition between various technological systems, both existing fully developed and emerging ones” (p. 633). Hence, an existing innovation system can possess inertia for the emergence of new TIS.

It is thus important to be able to identify the processes or actors that both can be considered as contributions to the emerging of a new technology. The reason for this is that it would be easier to design suitable policies that can help a (political desired) technology to develop further. It is equally important to identify the obstacles to technology development. This can provide decision-makers with information to design policies that can overcome possible societal and technical inertia that are in conflict with the Technological Innovation System. As Jacobsson & Bergek (2011) puts it: “A central proposition in the IS literature is that weaknesses in any of the elements may obstruct the development of the system (Carlsson and Jacobsson, 1997; Edquist, 1999; Malerba, 1996).” (p.45). Hence, system weaknesses are by many regarded as a core concept in innovation system analysis.

Path dependency

Innovation systems and technology development are often characterised by a degree of path dependence and lock-in. The theory about path dependency emphasises that any innovation system is dependent upon the historical development of the system. In terms of technology development, the notion connects to the fact that mature technologies will have comparative advantages compared to established and less mature technologies. Liebowitz & Margolis (1995) argue that some path dependencies can lead to inefficiency and market failure. One compelling empirical example is the development of the QWERTY keyboard as a standard. This choice was based on the avoidance of a jam by the metal arms in the typewriter in 1870s. Hence, the letters were placed such that neighbouring metal arms were least likely to be typed at the same time. This is the standard today, despite the evidence that other arrangements of letters would have allowed for faster typing. This example illustrates that the path dependence in technology development is highly applicable. For the study of technological innovation systems this concept should be regarded as central in order to understand the blocking mechanisms of the diffusion of new technology.

3.5.1 The seven functions of a TIS

There have been difficulties constructing consistent methods for the identification of the system weaknesses. Hence, efforts have been made in order to create a general framework for such an analysis that could be applied to any given TIS. One of the most promising approaches has been made by Bergek et al. (2008) where they identify seven functions that have to be present in the evolution of a TIS. “Functions are intermediate variables between structure and system performance; it is through the functions that components contribute to the overall “goal” of the system, i.e. to the development, diffusion and utilisation of new technologies." (Jacobsson & Bergek, 2011). The seven functions Bergek et al. (2008) identified are as follows[5]:

i) *Knowledge development and diffusion*

As a TIS develops across the different institutions and actors, knowledge grows and spreads around in the system. This is critical for the evolution of the technology, because more knowledge in all parts of the system leads to a better exploration and exploitation of the technology. It is a case of many complementary factors that pull in the same direction and grow together and learn from each other.

ii) *Entrepreneurial experimentation*

To be able to choose the best suited technology to solve a societal need or a problem, there has to be a degree of experimentation. This is due to the nature of immature technologies; their performance is uncertain and different solutions should be tested and explored in order for the best suitable technology to emerge. According to bergek et al. (2008) is the entrepreneurial experimentation the main source of reduction of the uncertainty which is connected to any evolving TIS.

iii) *Influence on the direction of search*

This function is about the presence of incentives for actors to enter the TIS and, consequently, that private and public actors start to search and identify the different technical and financial opportunities within the TIS. Firms and organisations must have incentives to contribute to the TIS. This could for instance be achieved through a belief in future growth, incentives through regulations and civil tort laws, or market demand (van Lente, 1993; Lundvall, 1992b; Porter, 1990).

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[5] The descriptions of the functions are partly based on the descriptions outlined by Bergek et al. (2008), but it is also based upon the writer of this thesis' own notions.

iv) *Resource mobilization*

Long-term conditions for the development of new technology are important. Long-term perspectives for investment in Research and Development are crucial for funding and initiatives from both private and public actors. This can for instance be educational institutions because of the need of required personnel; investments from private firms investing in technology; and applied and basic research in required fields, etc. Thus it is important to design policies that ensure a path of development that can be predicted, i.e. it can be argued that predictability is a key word in this function. In any emerging technology there is a critical need for resources, thus it is crucial to mobilise these resources in order develop the emerging technology. These resources have to be taken from other contexts; hence, there is a competition for qualified personnel and investments between technologies and sectors. Emerging technologies could have difficulties in competing with more mature technologies, For example, Jacobsson & Bergek (2011) states that "[…] government co-funding of demonstration plants (absorbing some of the risk) will probably be needed in the cases of CCS and gasified biomass[…]" (p. 50). The immature technologies are often in need of governmental investments in order to attract the resources needed.

v) *Market formation*

There is often the possibility of obstacles in the way when a technology is in the process of evolving from an idea or concept, to be launched in the market. In a changing TIS, either emerging or transforming, there are challenges to overcome in order to succeed in a commercial market. A market, to put it simply, is a place where demand and supply meet to find suitable price and quantity. If there is a larger social demand for a technology but the price does not reflect this, it could be appropriate for actors (private or public) to invest in a technology with an expectation of a long-term profit, when the technology has matured. A higher demand will lead to larger incentives for actors to devote resources in the technological innovation system. However, projecting which immature technology will be profitable is difficult, and it is unlikely that private companies will be first-movers in this regard.

vi) *Legitimation*

A high degree of social acceptance is essential for a TIS. This reflects the social desirability of the technology. It is reasonable to assume that if a technology is desired, there will be larger incentives for both politicians and private actors to participate in the development of the TIS that surrounds it. A desired technology will also be demanded, i.e. there will be a market demand for producing the technology. Bergek et al. (2008) argue that legitimacy is not something that is given, but rather formed through actions. Furthermore, legitimacy formation requires considerable time in order to mature. A long time horizon is expected.

vii) *Development of positive externalities*

A positive externality is often defined as a cost or benefit that is not reflected in the price; a so-called market failure. In neoclassical economics, externalities that are not implemented in the market should be corrected through interventions. Bergek et al. (2008, p. 418) state that the nature of SI strongly suggests that the "positive external economies is a key process in the formation and growth of a TIS". It is also argued in evolutionary literature that these externalities are not always pecuniary (Scietovsky, 1954, as cited in Bergek et al., 2008); that is, they cannot not always be measured in monetary terms.

3.6 Synthesis: functional analysis and the influence of NIS factors

In an extensive societal transformation such as the transformation of the energy system, it will be essential to apply both TIS and NIS analysis. In this thesis, both the technological and the national innovation system approaches are therefore applied. National specific characteristics are important because industry and energy structures differ between countries. Furthermore, the differences in the political environment make each country unique. However, an analysis of the innovations system surrounding renewable energy technologies is specifically limited to the technologies in focus. This will concentrate the analysis around relevant technologies.

Additionally, an appealing approach would be to analyse the interactions between the national and technological innovation systems. Could characteristics in the NIS of a country be an explanation for the performance of a TIS? This thesis will carry out an attempt to describe relevant factors in the Norwegian NIS and TIS for renewable energy technology.

The analysis of the TIS of renewables in Norway will be based upon the functional approach developed by Bergek et al. (2008). However, there will not be a complete TIS analysis of a specific technology. Rather, part of the analysis will be applied in order to say something about the Norwegian performance in the implementation of renewable energy technology. Furthermore, characteristics of the Norwegian Innovation System will be discussed as a reason behind the pace of technology implementation.

A choice to focus on three functions in a TIS analysis of renewable energy development in Norway in general has been made. These are:

1) Market formation
2) Resource mobilization
3) Legitimation

These three functions have been chosen because they were considered as especially relevant in order to answer and enlighten the research questions of this thesis. Furthermore, the writer of this thesis has a background in economics and science. These functions were thus appealing in order to say something about the Norwegian performance in renewable energy technology development based upon insights from economics and science.

4. Method

4.1 Research design

The case carried out in this thesis is an exploratory single case study. A case study has the advantage in that it gives the researcher the possibility "(…) to retain the holistic and meaningful characteristics of real-life events (…)" (Yin 2009, p.4). The case of "Norway as Europe's green battery" is indeed a highly real-life event. Furthermore, a TIS analysis seek to map real-life events in order to give provide decision-makers with information. In a TIS analysis many variables and actors involved, which has resulted in a complexity that is difficult to map and measure with quantitative data exclusively.

The case in this master thesis was identified early in the process, actually before the theoretical framework; the systemic approach to innovation (IS) in general and more specifically the Technological Innovation Systems (TIS). Consequently, the IS approach was chosen due to its interdisciplinary and holistic nature which suits the multifaceted case well. In addition, the systemic approach in innovation theory emphasises the complexity of the real world and one of its purposes is to map all the factors that influence the development, diffusion and use of innovations (Edquist, 1997).

The combination of the holistic view of the IS approach and the real-life character of the event resulted in an obvious choice of research method; the exploratory single case study research. . A single case is chosen due to the complexity of an innovation system analysis; there is simply not enough time in this master study to investigate several systems to compare them in a multiple case study. However, the use of the framework developed by Bergek et al. (2008) should make it possible to compare one functional analysis of technological innovations to the other. For example, relevant for this case study is the comparison of the development of renewables in Norway compared to European counterparts. Furthermore, it is essential to point at possible reasons behind the differences in performance of technological and national innovation systems.

Furthermore the specific TIS – approach has been used by several scholars in recent years to map the development of new renewable energy technologies (Jacobsson and Bergek, 2011; Markard and Truffer, 2008), thus the concept is appropriately applied to the case described in this thesis. Both case studies and TIS are emphasising the importance of decision making (Yin, 2009, p. 17; Jacobsson and Bergek, 2011). The seven functions of TIS which map the performance of the innovation system, is a central concept when it comes to connecting IS and policy issues regarding innovation and technology development.

This thesis seeks to contribute with an empirical case to this methodology. More specifically, Jacobsson and Bergek (2011) have outlined in their paper, "Innovation system analyses and sustainability transitions; Contributions and suggestions for further research", several suggestions for further research. Particularly relevant for this thesis have been "5.1 Measuring functionality" and "5.2 Interaction of TIS with higher system levels". The suggestions and the concepts from these two papers can be seen as the theoretical motivation for the methodology applied in this thesis.

4.2 Type of case

The complexity of the case has another implication on the method used in this thesis; namely how the data is collected. A contention stated in previous sections is that the Norwegian TIS of renewable energy lags behind and consequently finds itself in an immature phase. In order to gather information about Technical Innovation Systems that are in their emerging phases, I have opted to use multiple sources of information: interviews with central actors in the case have been conducted; research papers from researchers in the field have been studied; project reports made by consultancy agents and governments; and finally, different media sources regarding the issue have been analysed. The diversity of sources has been important to gather the required data. This is further enlightened in the section about validity and reliability.

As already stated, this thesis is greatly inspired by the scheme of analysis presented by Bergek et al. (2008) to use the innovation system approach to design practical guidelines for policy-makers.

4.3 Data sources / Data collection

4.3.1 Background research

First, the literature on Innovation Systems and Technological Innovation Systems in the context of the transition from conventional electricity production to renewable energy technologies was reviewed. Next, consultancy reports, research reports and media articles about increased electricity exchange between Norway and Europe were examined. Furthermore, statistics about Norway were revised. This statistical data described Norway's performance in the development of renewable energy resources. In addition, data and statistics about the Norwegian innovation system, industry structure and energy structure were examined. This was done in order to put the analytical approach into context and to understand the distinct Norwegian characteristics. In addition, a metasearch was conducted in the Norwegian media database "Retriever". Two Norwegian words for green battery were applied in a search and the amount of times the words had occurred in Norwegian media was exported to a figure (see figure 3).

The document reviews have resulted in several questions that emerged in order to contribute to the theoretical framework and the specific case. Consequently an interview guide was constructed in order to illuminate the chosen research questions and propositions.

4.3.2 Interviews

In this thesis several interviews have been conducted. These interviews have been made with actors that are connected in multiple ways with Norwegian energy production and its transmission system. A central idea has been to find interviewees that have diverse backgrounds and perspectives on the case. This has been done in order to see if there are recurring opinions and themes regarding the green battery case. The access to participants has however been limited by availability and time limitations. Furthermore, summer holidays and the relatively short period of time to conduct this thesis, restricted the possibilities for interviewees further. The interviewees were chosen due to their relevance of the Norwegian TIS of renewables in general, and the relevance to interconnecting cables in specific.

The interviews were conducted in Norwegian, and when the interviewees accepted it, they were recorded. There are particularly two reasons to use a tape recorder. First, it verifies the interview and how it was conducted. Second, it makes it easier for the researcher to concentrate on the conversation and the answers given by the informants. As previously mentioned, an interview guide was formed prior to the interviews, and further developed and changed throughout the interviews (see appendix). This was done due to minor changes that were made in the thesis' research questions and prepositions as the thesis was formed.

List of interviewees:

- Stein Vegar Larsen, Project Director the NORD.LINK / NorGer cable, Statnett.
- Håkon Egeland, Vice-president, Statkraft
- Anne Therese Gullberg, Researcher at CICERO.
- Detlef Sprinz, Professor at Potsdam Institute for Climate Impact Research.
- Henriette Nesheim, Assistant Director General at the Norwegian Ministry of Petroleum and Energy.
- Marte Bakken, Zero - the Zero Emissions Resource Organisation.
- Hans Erik Horn, Executive director production and environment, Energi Norge.

4.4 Validity and reliability

It is essential in all research to ensure good research quality. Perhaps is this particularly important in case studies, a type of study that uses methods where verification can be a challenge. Do the different data that are being studied in the case measure what they are supposed to measure? Is the information obtained verifiable? According to YIN (2009) there are four tests on the quality of social research (p. 40); three that involves the *validity* of the research design (construct validity, internal and external validity) and one that deals with the *reliability* of the case study.

4.4.1. Construct validity

This test is about the theoretical concepts used and the procedures or methods for measuring the desired object of study. To obtain construct validity, Yin (2009) identifies three tactics, i.e. use multiple sources of evidence; establish chain of evidence; and to have key informants to review the draft case study report (p.41). This thesis has collected data both in conducting interviews and in analysing different documents, which ensures the criteria of using multiple sources of evidence. The chain of evidence has been particular important when describing the different concepts in the theoretical framework. To enable the construction of logical connections between theory and empirical evidences the description of the theory has to be consistent and well formulated.

4.4.2 Internal validity

Is there a causal relationship between variables investigated in the study? This thesis has investigated relationships between different levels of innovation systems. In order to obtain an internal validity, this thesis has strived to identify all the different factors that influence Norway's contribution to the development of renewable energy. This has been the focus when the theoretical framework was constructed, as well as when the data was collected. During interviews it has been focused on asking open ended questions regarding the prepositions made in this thesis, as well as which alternative factors that could be influential. In addition, the interviewees have been asked about sources of information on the case. It has been asked for both suggested documents on the case and about who the key actors relevant for the case are. The thought behind this was to conduct what has been referred to as the "snowballing" method (Bergek et al., 2008, p. 413); to point out additional relevant sources of information.

4.4.3 External validity

External validity refers to the generalizability of the research carried out. Case studies must take additional precautions in order to be relevant for other events than just the case analysed. This thesis presents no data in terms of statistical generalizability, but seeks to contain an analytical generalizability, that is, an empirical case that expands general theories about systems of innovation. In addition to being relevant for theory contribution, it provides information and descriptions of Norwegian innovation systems. Such information can be important for decision-makers to construct the right policies on energy and on the environment. This case study thus contributes to an expanding of the general theory, as well as an illumination of the specific innovation system and possible policy challenges.

4.4.4. Reliability

This thesis has strived to be open about the research methods applied. The goal has been to be completely transparent, so that any reader of this thesis can identify the methods applied when collecting data and conducting research. This is done to ensure that other researchers can carry out the same case study as has been presented and expectantly end up with the same results and conclusions. One of the main criticisms of social science in general, and particularly case study research, has been the reliability of the research in the qualitative research made. Experiments in natural sciences contain variables that, in many circumstances, are more likely controllable. Hence, it is easier to sustain reliability. Precisely because of the existence of numerous uncontrolled and inexplicit variables in social sciences, it is utterly important to explain in detail how the research was carried out. To ensure reliability in this thesis the interview guide is included in the appendix. In addition, the audio files from the interviews are saved in a case study database folder. These documents can be obtained if required.

4.5 Improvement potential, biases and limitations

The open-ended interviews have contributed to insights and experiences from the informants that have contributed to the development of this thesis. However, such relatively unstructured interviews could be subject for biases. For example, some of the interviewees could have an own-interest in highlighting particular matters which are important for their objectives or agenda. It could be argued that representatives from both Energi Norge and Statnett could have an agenda in seeing more interconnecting cables being built. Thus, to avoid these biases, it has been pertinent to back up their arguments with additional sources of evidence when that has been possible. It has not been found significant discrepancies between documents and the informant's notions. However, their perspectives on the matter differed from what their positions were.

Further biases can encounter on the basis of the researcher's stand and voice in the empirical case studied. The researcher's background experience and social position can be relevant in this context. It has been important for the writer of this thesis to self-reflect over what consequences of the background experience and social position have been on the methods carried out and results obtained in this thesis. However, the thesis has focused on issues that the writer has experiences with, so this is a source to biases. For example, it is highly probable that the thesis would have been different if it were written by a student with a different background. Moreover, the selection process of informants and documents can well be subject to the writer of this thesis' previous experiences and knowledge. This emphasises that what role and perceptions the researcher has, is important in social sciences.

This master thesis is first and foremost limited by amount of words, time available for conducting research and the access to key informants. For example, a choice was made on focusing on only three functions. These functions were analysed with the resources and informants available. Furthermore, more throughout analysis of the national innovation system in Norway and the technological innovation system surrounding renewable energy technologies would have made the findings in this thesis stronger. That way, the interaction between a TIS and higher level innovation systems could have been better clarified and analysed.

4.5.1 Ethical concerns

Ethics in research is pertinent. To obtain ethical research, this thesis has followed ethical guidelines formulated by The National Committee for Research Ethics in Science and Technology (TENT)[6]. Before interviewing the informants, they were asked if it was acceptable if the interviews were recorded. The majority answered yes on this matter, but a few were not comfortable with being recorded. However, all the interviewees allowed themselves to be quoted and their statements to be used before conducting the interview. Furthermore, the documents used in this text are all public documents, research papers or newspaper articles.

5. The Norwegian NIS

This section will seek to outline the reasons for Norway's poor performance in renewable energy technologies, despite its great potential in exploiting these. Much of the background material presented in this section will be based upon innovation literature on the Norwegian political landscape and innovation system. The book, "Energirikdommens Paradokser" ("The Paradox of the Energy Riches"), written by Hanson, Kasa and Wicken in 2011, will be relevant and used for references.

5.1 The Norwegian Industry structure

"Norway *is* different than other countries in Europe" (Wicken, 2011, p. 127).

As has been outlined in the context chapter, Norway does not have pressing needs to decarbonise its electricity sector. The country is self-supplied in the electricity sector with renewable energy; the abundant hydro power in Norway covers 99% of the Norwegian

[6] The guidelines can be retrieved from this website: http://www.etikkom.no/no/Forskningsetikk/Etiske-retningslinjer/Forskningsetisk-sjekkliste/

electricity production (Statkraft, 2012)[7]. Hence, a strong focus on decarbonising the electricity sector does not exist in Norway. Furthermore, the existence of vast natural resources from gas and oil makes Norway a major exporter of petroleum and an average emitter of greenhouse gases in a European context.

The dominance of the petroleum sector in the Norwegian industry structure has certain implications for investments in renewable energy technologies. Firstly, the profitable petroleum sector attracts investments and resources. If financial capital and labour are regarded as scarce resources, which they in many cases are, there will be less financial capital and labour available for the rest of the industry.

Secondly, this has more long-term consequences: Years of a dominant petroleum industry has significantly shaped the Norwegian industry structure. In addition, the Norwegian research community, educational system, governmental institutions and the political landscape are all shaped by the dominance of the petroleum industry. This is a result of the historical development of the Norwegian industry sector, and particularly relevant for renewable energy technologies is the energy sector.

Such a historical development of industrial sectors is, in innovation theory, often referred to as path dependency or lock-in (Wicken, 2009). This path or lock-in could be hard to detach from. There are several reasons for this: politicians benefit from tax income in a high-profit industry; the educational system should educate students to sectors where the possibilities for jobs are good; the labour force will be attracted to the sectors where the wages are high; and researchers receive funds from the petroleum sector, because they most

[7] Note that these numbers do not include the offshore and transport sector, but refers to mainland consumption of electricity only.

likely can afford to pay for good research programmes. Thus, a dominant high-income sector can both in the short and the long run lead to less favourable conditions for competing sectors.

Wicken (2009) argues that the historical development of the Norwegian industry structure is a result of path dependency. The paths are created because Norway has specialised in the sector of industry in which it has historically been good at (similar to the notion of comparative advantage). The three paths Wicken has identified consist of: i) Small-scale decentralised path (e.g. fisheries); ii) Large-scale centralised path (e.g. natural resource industry); and iii) R&D intensive network based path (e.g. telecommunications). Wicken emphasises that this creation of layers is not unique to Norway, but that the importance of the different paths varies highly between countries. Thus, historical priorities and access to resources influences the way the composition and performance of the innovation system today.

5.2 The economic situation in Norway

“Keynes is alive!” (Prime Minister Jens Stoltenberg, 2009)

This section will briefly outline different characteristics of the Norwegian political economy structure and tradition. These characteristics are important in order to understand the pace of the development of renewable energy in Norway. This will be further discussed in section 7.

Norway has a strong tradition in state controlled economy (Wicken, 2011, p. 138). The government is involved in many decisions regarding the macro-economic situation in the country. During recent years Norway has been practising a countercyclical fiscal policy (e.g. Olsen, 1995). This means to vary government expenditure with business cycles; expand spending when the economy is weak, and to reduce it when the economy is strong. The idea is that the economy does not need any further investments in an economic upturn. To avoid an overheated economy and bubbles, the government should decrease its spending and rather accumulate capital. In addition, when an economy is expanding, prices on labour and capital are higher, and government spending has a lower effect. Conversely, when the economy is in a downturn, or a recession, the government should increase its spending to contribute to a faster recovery of the economy. This is inspired by the influential English economist John Maynard Keynes, known as one of the founders of macroeconomics and a supporter of governmental economic policies. This governmental control over the economy is strengthened by a high degree of centralised wage bargaining in Norway. This has helped the government to maintain control over aggregated salary levels, and to ensure wages that will help the export industry stay competitive.

The strong governance on the economy has appeared to be positive for Norway. It is one of the very few countries that has had a low unemployment rate through the financial crisis, which began in 2008. Moreover, Norway is today one of the richest countries in the world, with a GDP of 54,200 $, the highest in the world for countries bigger than 2.5 million inhabitants (CIA, 2011). Norway would obviously not have been in this fortunate position without its vast natural resources. However, there are examples of countries that have had (and have) access to natural resources without being able to maintain a long-term positive effect on the national economy. One of the most noticeable examples is the Netherlands in the 70's. It discovered gas resources in 1959 and exploited and exported these, which led to a boost in the Dutch economy. In brief, this resulted in a strong growth in the Dutch public sector, which grew more expensive to administrate. Furthermore, this caused a situation where capital and labour flowed from the private and internationally exposed sector to the public sector (partly due to a loss of competiveness because of high wages). When the income from the gas resources declined, the government did not have the funds to maintain the public sector. The government had to restrict spending in the public sector, and the private sector had already lost competitiveness. The Netherlands consequently went through a period with high wages, high unemployment rate and low international competiveness in the private sector. This is often referred to as the "Dutch Disease" (Ministry of Finance, n. d. b).

To avoid this situation, Norway has decided to create a sovereign wealth fund and a set of rules on how to use the profits from the petroleum industry in the economy. This rule is called the "Handlingsregelen" or "the Budgetary Rule", and was implemented by the labour party in 2001 (Ministry of Finance, n.d., c). A wealth fund was created, named "The Government Pension Fund – Global" ("Statens Pensjonsfond – Utland"), and rules on how to use capital from this fund were established. The main concept is that only the expected structural deficits in the state budget could be covered by an average of 4 % of the pension fund. The word *structural* implies that business cycles are taken into account; the expected income is calculated with respect to a typical year[8]. A budgetary rule will ensure a sustainable long-term development of the economy and provide Norway with a "back-up" fund that can be used during recessions. A budgetary rule will also provide stabile and long-term use of capital income from the petroleum sector, thus Norway will avoid the "Dutch Disease" and make certain that future generations will benefit from these resources.

[8] The use of structural profits and deficits is another example of counter-cyclical economic policies, the spending from the petroleum incomes should not exceed four percentage referred to a normal year, that is less in cyclical upturns and more cyclical downturns.

6. Analysis of the renewable energy TIS in Norway

“Functions are intermediate variables between structure and system performance; it is through the functions that components contribute to the overall “goal” of the system, i.e. to the development, diffusion and utilisation of new technologies.” (Jacobsson and Bergek, 2011, p. 46)

The current situation regarding the renewable energy TIS in Norway has been outlined in the context chapter. It has been argued that Norway lags behind in the development of renewable resources. This section will attempt to connect the theory about technological innovation systems described in the theoretical framework to the empirical situation in Norway. Thus, this section will seek to analyse the functional pattern of the Norwegian renewable energy technology technological innovation system (RET-TIS).

The analysis is largely based upon the functional analysis outlined by Bergek et al. (2008). A central strength of systems of innovation theory is the possibility to identify system failures. Barriers to innovation can be identified through a system analysis. This creates the possibility to provide decision-makers with information in order to design appropriate energy and climate policies. This will expectantly contribute to identify and influence structural factors that block the performance of the innovation system. This was also the motive for developing the notion of functions in a TIS analysis (Jacobsson and Bergek, 2011).

As justified in the theoretical framework the focus will be upon three of the seven functions:

i) Market formation

ii) Resource mobilization

iii) Legitimation

The functionality of these three functions will consequently be analysed with the findings from the empirical investigations carried out, i.e. mainly through documents analysed and interviews conducted. Furthermore, it will be argued that there are blocking mechanisms that hamper the development of these functions in Norway.

6.1 Market formation

In what state is the market for renewable energy in Norway? It will be argued that there are two different restrictions on market formation for renewable energy in Norway: i) Physical market limitation; the market for distributing electricity produced is physically limited by the power grid; and ii) economic; there have been considerable limitations in the market for renewable energy in Norway. This has led to a lack of incentives for investments in renewable energy.

6.1.1 Physical limitation; electricity grid

The physical limitation restricts the possibilities of distributing renewable electricity from the source to consumers. Having more sources of energy implies that more transmission capacity is needed. A well-functioning grid of power cables is a fundamental infrastructure equipment in order to distribute electricity from renewable sources to the consumers efficiently. Hence, the central grid in Norway needs to be upgraded. This is becoming more pertinent along with the development of new renewable energy as for instance wind power, because of the fluctuating production of electricity. In contrast to hydro power and thermal power plants based on fossil fuels, wind power varies with weather conditions. This poses a challenge to the grid, because electricity must be transferred to where the demand is, based on unstable weather conditions.

However, it is not only the central grid that could be modernised. As already mentioned, Norway’s electricity demand is to a large extent covered by hydro power. To avoid a lock-in of the electricity produced in Norway, an increased interconnecting capacity with Europe could be beneficial. In an electricity system that is isolated, electricity produced should be equal electricity consumed. This will lead to few incentives to invest in new sources, when there is no demand for more electricity.

The more the Norwegian grid is interconnected with Europe, the more flexible could the production of electricity be. Instead of having a constant balance between supply and demand, the different energy producers can produce electricity when their conditions are good. Europe is in need of a flexible distribution of electricity due to an extensive development of renewable energy. Norway could sell excess energy on the European electricity market; Norway could provide Europe with electricity from hydro power plants, and Norway could buy cheap excess electricity on the European market. Furthermore, this could also contribute to a better market for renewable energy in Europe in general. The efficiency of renewable energy technologies in Europe could be improved if a flexible grid system was introduced. This would in turn allocate electricity more efficiently. Thus it can be argued that a construction of an extensive power grid is essential in order to provide a well-functioning market for electricity stemming from renewable sources, both in Norway and in Europe.

This weakness in the TIS of renewable energy is of a transnational nature; there have to be international political agreements on to what extent such a grid should be developed. Political will have to appear on a national level in Norway. Only then will it be possible to make international agreements on an interconnected European grid and a common European electricity market. This aspect will discussed further in section 7.2.

6.1.2 Market limitations due to lack of economic incentives and stable and overarching framework conditions

This section will argue that much of the market limitations for investments in renewable energy in Norway are connected to risk and predictability. Moreover, the economic tradition in Norway can be said to have contributed to an exacerbation of this aspect. Investments made by the Norwegian government are characterised by cost benefit analyses (Senter for Statlig Økonomistyring, 2010, p.5), in which every investment is measured against a hypothetical future return on the sovereign pension fund (set to 4%). This could have severe implications for projects that have uncertain benefits and costs; e.g. governmental long-term investments in essential infrastructure such as power cables.

Liberalisation in the electricity market

The Norwegian electricity market was liberalised, as one of the first in Europe, in 1991. This has led to market price of power, which fluctuates with supply and demand of electricity. Supply is dependent upon the amount of annual rain, because of Norway's high share of hydro power. The rate of development since this deregulation has been low, see figure 4. The reasons are multifaceted, but low expected electricity prices due to low expected increase in electricity demand is an important factor. In addition, the easiest accessible power plants that did not have severe impacts on conserved nature have already been exploited. A small increase in investments can be seen from 2006. This increase could be due to higher prices on electricity in recent years (SSB 2012a). This emphasises the importance of the electricity price for investments in renewable energy.

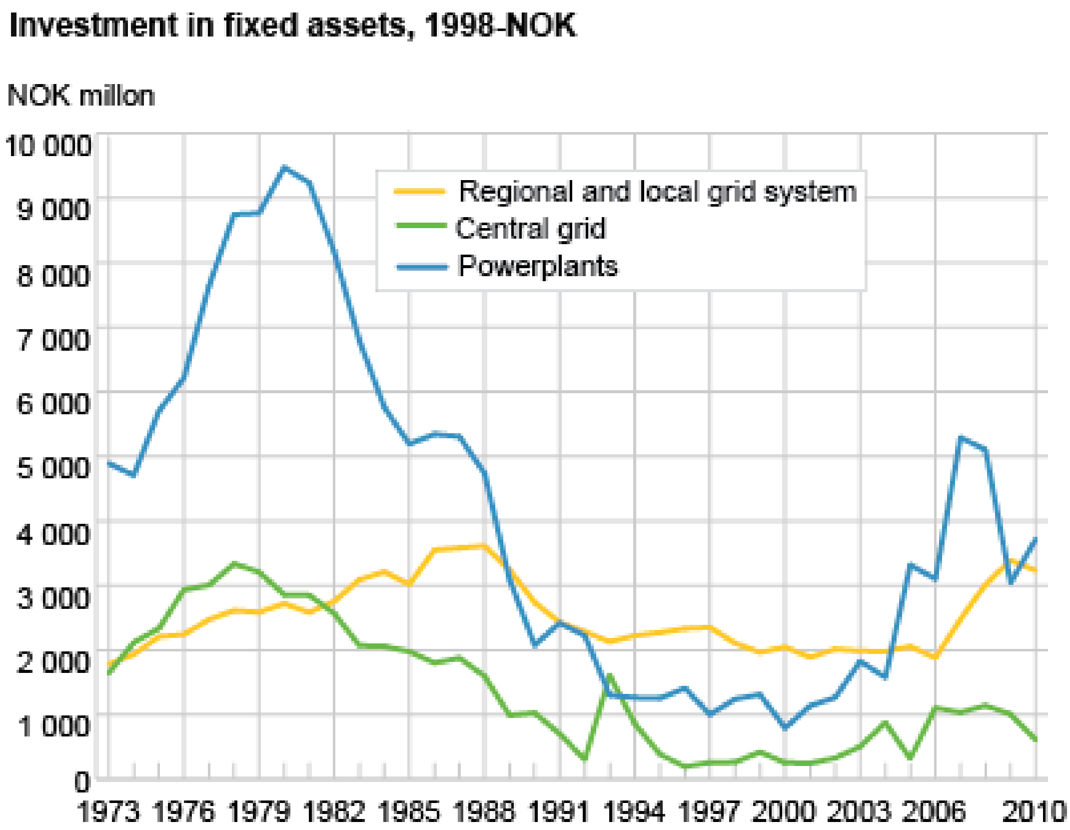

Figure 4. Investments in grid and renewable energy in Norway from 1973 to 2010. A sharp decline in investments can be seen around 1991, the year the market was liberalised (Statistisk Sentralbyrå (SSB), 2012a).

Nevertheless, the liberalised market has not provided investors with incentives to invest in renewable energy in Norway in recent years. This has been much debated in the Norwegian political landscape, and several expositions have been carried out in order to increase these incentives. More consistent framework conditions are something that have been requested by several actors in the RET-TIS in Norway (see for instance Lie, Ø., 2011).

To obtain a viewpoint from the electricity producers in Norway, Hans Erik Horn was interviewed. He is the executive director of Production and Environment in Energy Norway (Energi Norge). This is a non-profit industry organization representing about 270 companies involved in the production, distribution and trading of electricity in Norway (Energi Norge, 2012). Energy Norway thus represents almost all investors in energy in Norway. He expresses his concerns regarding the difficulties with long-term planning in the energy system:

> It is difficult to make politicians think more than four years ahead […] Systems that have such long time constants as the energy system. It is actually not very well suited for political micromanagement. […] Then there has to exist some [political] frames, and these frames should be held on to. There are some political rarities such as a decision is valid until a new decision is made. You have taxes that constantly change. And you have political celebration decisions [festvedtak], such as The Climate Compromise [klimaforliket] and such things, which do not manifest themselves in act. If you are going to invest your 1000 [kroner] bill in something you really think will give profit, you will maybe be a bit sceptical to the framework conditions of the energy system. Unfortunately. (H. E. Horn, personal communication, august 27, 2012)

This statement sums up the horizon mismatch associated with a longer term energy view, and a shorter term view of politicians. As well as the common view that investments in renewable energy are in need of stable framework conditions. Any investor would like to have framework conditions that are predictable, which is not the case for renewable energy technology in Norway. The volatile nature of electricity prices and changing energy policies are making investments in renewable energy a high-risk activity. In order to increase investments in new renewable energy, Hans Erik Horn suggests more long-term "overarching policy framework conditions" (personal communication, august 27, 2012). This will secure a more steady return on renewable energy investments, and hence generate more incentives for investors to invest.

Green certificates as a facilitator for market formation; criticism and consequences

Norway has not had any regular subsidy[9] scheme for renewable energy until 2012[10]. The implementation of the green certificates (TGC) in January 2012 is meant to provide investors with more incentives to invest in renewable energy. However, the result of this instrument is highly disputed. Norway has chosen to implement a trade scheme for renewable energy that has been met with criticism from many angles. Both evolutionary economists as well as traditional Norwegian economists seem to agree that the system with green certificates is not a very efficient tool for promoting the development of renewable energy. In particular, two criticisms have been repeated in the Norwegian debate: i) it is doubtful that TGC will have a severe effect on the total emissions of CO_2 in the current energy system; and ii) TGC does not promote the development of immature renewable energy technology sufficient enough.

Bergek and Jacobsson (2011) have measured the effects the green certificates have had in Sweden, and conclude that it is a “machine that creates interest rates”. This implicates that the producers of electricity are being overcompensated and that consumers are being unnecessary taxed. 28% of all taxes paid in the Swedish green certificate system are overcompensation. Furthermore, Bergek and Jacobsson (2011, p. 101) conclude that:

> If the society means that it is important with industrial development and technological development, or wishes to keep the extra profit [for the producers of electricity] low to maximize increased production with available funding in the policy instrument, one should look for other alternatives.

Furthermore, people in the economic academic community in Norway have several times expressed their scepticism regarding green certificates. This was perhaps expected.

[9] Subsidies in this context will refer to subsidy as any financial assistance in the production of a good. Thus, with this definition, the green certificates are subsidies for the producers of green energy.
[10] Previously it was possible to receive support for renewable energy production from a fund controlled by ENOVA. ENOVA is a public enterprise that is owned by the Ministry of Petroleum and Energy and promotes renewable energy and more efficient energy consumption.

Economists often prefer taxes before subsidies when dealing with externalities. This is preferred because the efficiency loss is expected to be lower, according to optimal tax theory.[11] Economists in Norway are influential and are probably part of the reason why there has not been any regular subsidy scheme before 2012. However, the economists Bye and Hoel (2009) write in the article "Green certificates – expensive and purposeless renewable fun" that this is not only an expensive way of subsidising renewable energy, but would probably have no effect at all on carbon emissions. They point at the special situation in Norway; the electricity production is already renewable and the extra production of renewable energy will probably go to export. Further, they argue that the green certificates scheme consequently is a subsidy paid by Norwegian consumers to export renewable energy to Europe (provided adequate transmission capacity in the interconnecting cables). With the advent of the emission trading scheme in Europe, this will not cause an increased share of renewable energy, but rather free up emissions for other countries in the EU. The total effect will be that the emissions are relocated from one country to another. Bye and Hoel argue that it actually would be more cost-efficient to use the funds used for green certificates to buy emissions from European countries and simply throw them away; at least if the goal is to reduce the total amount of carbon dioxide emitted in Europe.

The other major criticism of the green certificates trading scheme, that it does not support emerging technologies sufficiently (cf. the conclusion from Bergek & Jacobsson (2011) cited above), is highly relevant for literature on innovation and evolutionary economics. The green certificates scheme is technology neutral, i.e. it gives the same subsidy to all renewable energy technologies. This means that it will be preferable for investors to

[11] A tax will provide a downward shift in a demand curve because of the higher prices, leading to lower consumption of the good that gives a negative externality. When subsidizing, this shift will not occur.

invest in technologies that are mature and which can give a return in a relatively short period of time. In Norway this will probably lead to increased investments in already existing hydro power plants. If a subsidy is meant to facilitate for the development of new technologies through experimentation and increased investments, it may not be very efficient that the majority of the funds go to an already profitable and mature industry.

However, despite these criticisms the tradable commodity was implemented in January 2012. The TGC is expected to add 26.4 TWh of electricity by 2020 in Norway and Sweden. This will be added to the existing supply of electricity. If we assume that we do not electrify the offshore sector or witness a significant increase in the demand of electricity in inland Norway before 2020 (e.g. through more electrical cars or more energy intensive industry), what will the consequences be?

Consequences of increased share of renewable electricity in Norway

An increased development of renewable energy, without phasing out other sources of energy, will lead to a higher supply of electricity in the Norwegian market. Subsequently, according to basic economics, this will result in a) lower prices on electricity; and consequently b) a higher consumption of electricity. How comprehensive these effects will be, is dependent upon the shapes of the supply and demand curves. There are reasons to assume that Norwegian electricity consumers, both households and industry, are affected by fluctuations in the prices; total Norwegian electricity consumption will adjust to these fluctuations. For example lower electricity prices could lead to less economic incentives for daylight savings. Moreover, this could also lead to lower costs for energy intensive industry causing higher production in this sector. In economic words, the demand curve for electricity is not inelastic. This means that Norway is in a situation where further development of renewable energy will lead to lower prices in the market for electricity. A drop in the prices for electricity will yield lower returns from power plants. This is counter-productive for investments in renewable energy, because investors in renewable energy will receive lower returns when they sell electricity in the market (cf. Hans Erik Horn's statements). In addition, as previously briefly mentioned, lower electricity prices will most likely lead to higher consumption of electricity in Norway.

TGC will expectantly create a market for developing 26.4 TWh of renewable electricity in Norway and Sweden, but the size of the supply side of the market is highly uncertain. We are hence looking at two probable outcomes of an expected increased share of renewable energy in Norway: i) that prices on electricity, and conceivably investments in power plants, will decline; and ii) that total electricity consumption goes up. Because of this outcome it is worth asking: is this a good strategy for the Norwegian contribution to avoid global warming? This is an important and relevant question because we know that building more hydro power capacity and wind power requires intervention in nature. It is appropriate to mention that Norway has the second highest consumption of electricity per capita in the world (The World Bank, 2009). The electricity consumption per capita is twice the amount of the consumption per capita in the United States.

6.2 Resource mobilization

6.2.1 Resource needs

In an emerging TIS it is essential to mobilize capital. Financial investments are important in order to purchase labour and equipment needed for the R&D of the technology, and in the construction of technology itself, such as e.g. wind turbines. Nevertheless, capital itself cannot develop a technology. Thus, the access to human capital is critical for a TIS to evolve. Human capital in a country is provided through the work force and more fundamentally through the educational system. Resources for renewable energy technologies are not necessarily easily accessible. For example, Jacobsson and Karltorp (2011) have estimated that there is a need for 9000 engineers in the EU at wind turbine manufacturers until 2020. These engineers need to be taken from related and competing technological industries. In addition they argue that there is a need for educational programmes in order to provide the specific competence needed. Furthermore, financial investments are needed in order to develop energy technology and new power plants in Norway. As figure 4 in the last section shows, the investments in Norwegian power plants have been low since 1990.

Resources are also needed in order to develop the electricity grid for the support of new energy sources. To further develop the grid and to construct interconnecting cables with surrounding countries, resources must be mobilized in order to construct high-voltage lines and cables. There is increased investment activity by the Norwegian government in grid capacity. Today, an investment of 40-45 billion NOK before 2020 is planned. The capacity of the Norwegian TSO Statnett is fully utilized. Further projects must receive more support from the government, and they have to be planned after 2020 (S. V. Larsen, personal communication, May 25 2012). The representative at Statnett, Stein Vegar Larsen, states that it is not physically possible to build more than what is now planned for 2020. This is due to what resources Statnett has available at the moment and the tedious process of licenses for grid construction. Furthermore, Larsen says that some of the German roadmaps to a 100% renewable electricity sector “are totally unrealistic on behalf of Norway”. Norwegian infrastructure conditions should be taken more into consideration. Currently, there is today a lack of resources available for the development of 50 GW interconnecting cables. In addition, it appears to be a problem with legitimation in the Norwegian population for a project of that size. As outlined in the theoretical chapter of this thesis, legitimation is important for new technologies. Legitimation of renewable energy and building of grid and interconnectors is the focus in section 6.3.

6.2.2 Hampering factors

Much of the Norwegian national innovation system is built around what historically have been important industries in Norway. And in recent years we have seen a shift towards the offshore oil and gas sector; the Norwegian industry structure is today characterised by decades of a very profitable petroleum sector. The dominance of the petroleum sector is outlined in the context section and in section 5.1.

The relative high profits and activity in the petroleum sector does also lead to the ability to offer higher wages. This gives the petroleum sector a comparative advantage compared to the renewable energy sector (or any other sector in Norway) in terms of the ability to attract highly skilled labour. Hence, in order to mobilize resources to alternative energy technologies, these technologies must compete with the petroleum sector. In addition to this, Norway has had, and has, a low unemployment rate (SSB, 2012b), with close to a fully utilised workforce. Furthermore, there is already a deficit of trained engineers in Norway (Sørbø, J. & Jacobsen,K, 2012). This indicates that labour in general, and engineers in specific, are scarce resources in Norway. Hence, labour for renewable energy technologies must be attracted from other sectors or from abroad.

The scarcity of human resources in Norway gives the less established industry tougher conditions. As we have seen, there is a hard competition for labour in general and specifically a highly skilled workforce such as engineers. This combined with a general scarcity of engineers in Europe (cf. Jacobsson and Karltorp, 2011) makes this function even more central in the development of renewable energy and its infrastructure.

It can be argued that a neoclassical approach to investments in technology amplifies the problems inherent in the mobilization of financial resources to immature energy technologies. In a cost-benefit analysis, immature technologies will often lose against established technologies. This has implications for investments in these technologies; private investors seek the most profitable investments. Moreover, Norway has a risk-averse management of the pension fund, where the criteria are highest possible return with a moderate risk (Ministry of Finance, n.d. a). It can thus be expected that investments in supporting infrastructure will have to compete against an annual rate of return of 4%. With such an investment strategy it can be difficult to justify long-term infrastructure development funded by the pension fund. Such an investment strategy could leave immature technologies behind in terms of infrastructural support from the government.

Another example of a neoclassical approach to technology development can be found in the green certificates trading scheme. TGC is technology neutral, leading to investments in the most profitable renewable energy technologies. In Norway today that is hydro power, a technology which has matured for more than one hundred years. Green certificates have made this technology even more profitable, and they have made it more attractive for investors to upgrade existing plants or build new smaller power plants. The latter is limited by few licenses for bigger projects. The result is more investments in well-known and profitable technology and few investments in immature technologies (Bergek & Jacobsson, 2011, p. 97). Consequently and again, if one of the ideas with the TGC is to facilitate the development of immature renewable energy technologies, a technology neutral support is not necessarily the best approach.

6.3 Legitimation

The importance of social acceptance of technology is fundamental for the development of a technology. Legitimation is important for the overall functional performance in a TIS, because it is difficult for actors to work with technologies that have no legitimacy or no goodwill. For a technology to develop, actors must have an interest in implementing the technology in society. For the development of renewable energy in Norway, barriers to legitimation are found on multiple levels.

Firstly, construction of high-voltage lines, wind power plants and more hydro power plants have been controversial in Norwegian politics in recent years. High-voltage lines and wind turbines are characterised by a high degree of Not in My Backyard (NIMBY) challenges and legitimation for new lines can be regarded as low in certain areas (e. g. Fröhlingsdorf, 2011). This is true in the broader Norwegian context; the increased activity in Norwegian grid development during recent years has met resistance from locals. One compelling example is the case regarding high-voltage lines in the fjord of Hardanger in 2009 (Nielsen, Glomnes, Andersen, 2010). The planned construction of high-voltage lines was met by substantial criticism from locals and environmental organisations. The government had to intervene and rule out a new hearing on the matter. The lines will be built, but the project has been subject to a severe delay.

There seems to be a gap between legitimacy of the construction of power grids and the construction of new renewable energy sources. According to a German survey, 87 % of respondents stated that new offshore wind power plants should be built. Furthermore, 78 %

were positive to more onshore wind power construction. When the respondents were asked about the construction of a power grid, however, they were significantly more sceptical. Only 42 % wished that more high-voltage lines should be constructed (Lie, Ø., 2012). This compelling example illustrates once more that constructing power grid is a challenge in Germany. The case about the high-voltage lines in Hardanger implies that the situation in Norway is not very dissimilar.

Another legitimation issue connected to grid construction is that of the consequences this construction will have on electricity prices. Prices in Norway are expected to increase with an increased integration and trade with Europe (Thema Consulting, 2012). Consumers of electricity will hardly welcome an increase in electricity prices. There are two main consumers of electricity in Norway, private households and industry. The majority of households will naturally oppose any increase in electricity prices. Moreover, the industry is not interested in increased expenses on electricity. This is especially important for the energy-intensive industry, an industry sector that has had comparative advantage in Norway due to low Norwegian electricity prices.

In order to understand the viewpoint of Norwegian governmental institutions, an interview with Henriette Nesheim, Assistant Director General at the Ministry of Petroleum and Energy, was conducted. She addressed the challenge with legitimation regarding interconnecting cables and a possible increase in electricity prices to the lack of legitimacy in the population of Norway: “There is a common perception that electrical power should be cheap and that Norway should be self-sufficient with this” (personal communication, June 11, 2012). Furthermore, she stressed the importance of “public education”. She stated that resistance in the population could be due to too little information about the possible positive effects on climate change, as well as a possible profitable industry for Norway, to which an increased exchange of energy could lead. “There is a need to get people involved in a possible exchange of electricity. […] When people see the profits in electricity exchange, and when they get information about the positive climate effects, they seem to be positive about the project” (personal communication, June 11, 2012).

To further illustrate the political opposition against an electricity exchange with Europe, the Norwegian Minister of Petroleum and Energy, Ola Borten Moe (SP), is quoted. The Norwegian newspaper Morgenbladet (Jørgensen, S. I.,2011) has quoted him from a lecture held at the University of Oslo:

> I am not one of those who think that the potential for regulating in Europe can be solved by Norwegian pumped storage power plants [sic]. I think we have to consider the environmental consequences. If the “Blåsjø” – reservoir should start to be elevated and lowered by 10 meters every 24 hours, it could be someone who would react on that […] Secondly this type of power transmission will require huge investments and interventions in the form of cables and high-voltage transmission towers […] When it comes to the capacity of regulation which Norway can deliver to Europe, it is first and foremost with gas this is possible.

There is a considerable problem with legitimacy associated with the construction of renewable energy facilities in general. Besides, the construction of supporting infrastructural grid capacity is particularly controversial. As we have seen, barriers exist mostly on a political level. However, they are affected by distinct characteristics in the Norwegian industry and energy structure. These barriers must gain attention in order to shift the development of renewable energy into a higher gear. This thesis will return to the challenges regarding legitimacy in transforming the electricity market and system in Norway in discussion, Norway as Europe’s green battery section 7.2.

7. Discussion: Norwegian characteristics; implications and a possible solution

In the context part of this thesis the energy system of Norway has been described. It has been stated that there exists abundant energy resources in Norway, and that has implications on the rate of the diffusion of renewable energy technologies in Norway. Furthermore, in section 5, characteristics about the Norwegian industry and economic structure have been outlined. Section 7.1 will discuss if the strong tradition of socio-economic approach could be a barrier to the development of renewable energy in Norway. Consequently, section 7.2 will discuss the importance of grid development for renewable energy technologies. This latter part will hence seek to enlighten the second research question of this thesis: is an increased exchange of electricity between Norway and Europe feasible.

7.1 Neoclassical economics and technology development

"In the long run we're all dead" (John Maynard Keynes).

Which implications does the economic tradition have on the development of renewable energy technologies in Norway? Could this be a barrier to the development of immature renewable energy technologies? These questions are central and it will be argued that the economic tradition could have negative impacts on the development of renewable energy. The discussion will be based upon the discrepancy of the neo-classical economic approach and the evolutionary economic approach to technology development.

Firstly, neoclassical selection mechanisms for investment in technology use the concept of marginal costs as a basic tool. The most cost-efficient technologies to date will receive investments. It is argued by Jacobsson and Bergek (2011) that this approach is not sufficient in order to develop technologies with the greatest potential. A neoclassical approach will fail to take non-economic aspects of technology into account. For example, a neoclassical selection process will struggle to consider politically desired characteristics of a technology. This could be the greenness of electricity production or the total picture of positive or negative externalities related to each technology.

Secondly, neoclassical economics is highly based upon the notion of market failures when dealing with both pollution and technological development. More specifically, this is the concept of externalities. The idea is that there exist both negative and positive externalities that disturb the perfect market solution, which is considered as the socially optimal solution. These are costs or benefits that are not reflected in the supply and demand curves, and hence not implemented in the price of the goods and consequently the quantity sold. The emission of CO_2 is a negative externality which stems from the production of electricity from fossil fuels. Technological development is often considered a positive externality that is derived from investments in education, R&D and research.

Pigouvian tax and subsidy are the economic tools typically used for both reducing carbon emissions and for the emergence of specific technological solutions. Pigouvian taxes are taxes that should reflect the externality costs, the tax should thus be set at a sum equal to the costs the externality causes society. Hence, the tax should internalise potential externality costs and benefits (Bernheim & Winston, 2008, p. 770). When the externality is represented by pollution, this tax is often referred to as the “polluter pays principle”.

On the other hand, dealing with positive externalities such as renewable energy technology development is an externality that is wanted. To encourage such positive externalities, alternative technologies or products can be taxed, or the desirable technology or product can be subsidised. In that way a desired tax shift can occur, as consumers will turn to the product that has the most positive externalities because the price will be relatively cheaper. Taxes have historically proven to be an efficient tool for including social costs such as pollution in to private costs, i.e. the market price, and thus allowing the market facilitate the development of an alternative technology. A recent example of this is the tax levied on CFCs (chlorofluorocarbons) through the Montreal protocol in 1987. CFCs today are forbidden and not in commercial use. Another example is that a significant part of the reduction of local pollution the recent years can be credited to well-designed tax solutions for Sulphides and Nitroxides.

However, to find the perfect market solution, many variables must be determined and predictions on how the market will evolve must occur. This may be difficult to achieve. Additionally, uncertainties in these variables and predictions are highly relevant when dealing with greenhouse gases and development of technology. The consequences of carbon pollution are hard to measure, cf. the debate in UN’s climate panel. What is the external cost of carbon emissions? Or more specifically, what will it cost society if the sea level rises with 3, 5 or 8 centimetres over the next 40 years? Or what is the willingness of consumers to pay for these extra costs? These numbers are hard, if not impossible, to calculate because data is uncertain. Furthermore, the political and economic world is complex; increased concentration of CO_2 in the atmosphere will induce diverse consequences to different countries. Hence, the incentives for reducing carbon emissions will vary between countries. The high degree of uncertainties associated with the numbers implies that it is doubtful that a perfect market solution can be obtained.

Furthermore, there are challenges constructing decent economic models due to the time aspect of both the consequences of CO_2 emissions and the development of technologies. The consequences of an increased concentration of CO_2 in the atmosphere will not be felt until much later. Besides, costs and revenues connected to emerging technologies change drastically over time. The most cost-efficient technologies today are not necessarily the most cost-efficient technologies in the long run. As the surrounding conditions for a technology change, so do willingness to pay and the costs of production, development and manufacturing. These variations are hard to take into account in economic models, and the result is that mature technologies will be preferred in an open market. This leaves investments in immature technologies behind, because the risk in these is too high.

In innovation theory the concept of technological innovation systems (TIS) involves all actors and institutions that surround a technology. For immature technologies, this TIS is in a formative or emerging phase. These phases are characterised by constant changes in framework conditions and their supporting institutions. In an emerging TIS the different actors and institutions find themselves in a process of learning, with accumulation and diffusion of knowledge throughout the system. There is a lot of focus on how knowledge is managed in the society in the innovation literature (e.g. Powell and Grodal, 2005, p. 75; Asheim & Gertler, 2005, p. 293) and this is particularly fundamental in a changing TIS. In order for a technology to develop into a growth phase, management of knowledge should have a focus. Maximising the output of knowledge is not a straightforward process. Hence, detailed information about technological systems is crucial for decision-makers in order to make good decisions on knowledge management.

Moreover, there are reasons to believe that learning processes influence the prices of a technology, as well as the efficiency of the technology. This is because a better understanding of the technology and its supporting structures are needed for a technology to develop. An increased knowledge about the technology could lead to better ways of improving and manufacturing the technology. Consequently this will lead to higher demand or lower costs on the supply side. Hence, market conditions have changed, and the economic models must adapt to these changes.

Hence, the development of renewable energy technologies is a process that requires time, as it has a long time frame and the externalities connected to both technology development and carbon emissions are uncertain. It can thus be argued that a neoclassical approach to the development of renewable energy technology is not sufficient in Norway. On behalf of this contention, this thesis claims the same as Jacobsson and Bergek (2011): “that technology-specific policies are necessary if we are to meet the climate change” (p. 41).

7.2 The importance of grid development and its legitimacy challenges

As we have seen, an increase of renewable energy production in Norway does not per se necessarily reduce carbon emissions globally. Furthermore, uncertainties related to the future price of electricity may be an obstacle in order for investment in renewable energy. One of the main challenges is that there seems to be a lack of a strategy for the demand side of increased electricity in the Norwegian market. One solution could be to exchange electricity with Europe to a greater extent. This section will discuss the consequences of an increased exchange of electricity between Norway and Europe. Is such a solution feasible?

More electricity exchange and a more volatile electricity production demands a stronger electrical grid system. The construction of power grids is a process that requires time, and as we have seen, legitimacy. Many considerations have to be analysed and several actors are involved. A normal timeframe spans between 10 and 15 years from the start of planning a power cable or high-voltage line until it is completed. This is due to the license process connected to power lines. Local resistance due to nature interventions are common; everyone has the right to appeal on a decision. Bureaucracy takes time, and the grid must be operative while it is being upgraded. As the project director in the Norwegian TSO Statnett, Stein Vegar Larsen, expresses:

> To get licenses for new transmission grids, new power grid lines, and maybe particularly on the German side, but also on the Norwegian side, that is a project that lasts for 10-15 years. This is due to the problematic conditions regarding licenses. So all the TSO's are lagging behind, because it is much faster to establish new production. It takes much longer time to establish a new grid. […] This is a central challenge (S. V. Larsen, personal communication, May 25 2012).

It can thus be argued that in order to develop new renewable energy facilities, the electrical transmission grid has to be in the forefront, i.e. there is a need of long-term plans in grid development. These plans must be visionary and consistent with the development of new renewable energy. A well-functioning market for renewable energy is hence in need of a transmission grid that can connect the producers of energy, the supply side, with the consumers of the electricity, the demand side.

As has been outlined in the context chapter, there is a desire from German actors that Norway should be a part of the transformation of the German energy sector. The SRU report has assumed that Norway could function as a balancing part of the European energy system with its hydro power capacity. Norway could balance the unpredictable renewable sources of electricity by selling hydro power to the market when there is need for electricity. Furthermore, Norway could buy excess renewable energy when wind is strong and demand is low. According to SRU, this could be done with the construction of interconnecting cables between Norway and Germany with a capacity of 50GW. Compared to the current capacity of 1400 MW (1.4 GW), this is an extensive project.

On the Norwegian side of the debate, a consulting report was made by Thema Consulting Group in March 2012: “Fornybarutbygging og Mellomlandsforbindelser mot 2020” (“Development of renewables and interconnectors towards 2020”). This report presented the welfare economic impacts of the construction of four cables between Norway and to the European continent, including the UK. Four scenarios were carried out and all four gave a positive welfare economic output. This indicates that the construction of these cables will yield a positive economic result for Norway. However, the scenarios presented in this report are not by far as extensive as what is suggested by SRU's report (2011). In the scenarios evaluated in the Thema report, the development of new cables with a maximum capacity of 4500 MW has been used in their calculations. This includes new cables between Norway and Germany (2400 MW), UK (1400 MW) and the Netherlands (700 MW). As mentioned the development of 1400 MW cables to Germany and the UK cable are in progress.

There is to date a discrepancy between what looks politically and technologically feasible between the Norwegian and German suggestions. It is important to state that the time scales are radically different. The Germans look to 2050, while the Norwegian outlook ends in 2020. Furthermore, the starting points for the analysis are distinctly different between the two reports. Thema Consulting Group’s perspective is about what development is beneficial for Norway in welfare economic terms. This is consistent with the general Norwegian investment strategy. The SRU’s analysis is more concerned on what, for Germany, would be the most cost-efficient and feasible roadmap towards a 100% renewable electricity sector by 2050.

Despite the different perspectives, time-horizons and goals, it is noteworthy that the Thema report's firm conclusion is that "these interconnectors should be realized sooner rather than later". The report justifies this with the arguments that it will contribute to a more renewable energy system in Europe and that it will yield a positive welfare economic result for Norway. More specifically the report states that: interconnectors will contribute to an increased integration and power trade in Europe which will lead to a more efficient use of energy resources; a better regulation of Norwegian power plants; it will yield congestion rents, stability in the electricity prices, positive climate effects and the possibility for an increased sale of regulating services.

However, despite the possible positive effects of an increased exchange of electricity, there are uncertainties related to how profitable it will be for Norwegian actors. What effect will an increased integration with the European power market have on electricity prices in Norway? The Thema report has shown that the construction of interconnecting cables will lead to higher prices. The price effect for the first cables is, however, small. Thema Consulting has calculated that continental prices will not be imported, but a small increase of about 1-2 % is expected (Thema Consulting, 2012). A more extensive development of interconnecting cables, such as the scenario from the SRU report, is thus expected to further increase the prices to the European level. This will have implications for Norwegian industry and private households. Nevertheless, the overall impact is exaggerated. The Norwegian electricity price has increased since 2000, and from 2003 the price for households has been approximately the same as the average in OECD (SSB, 2009).

This raises an important question: are there enough incentives for Norway to participate in the transformation of the European electricity sector? With uncertainties connected to costs of grid development, prices on electricity, possible less favourable framework conditions and significant interventions in Norwegian nature, this project could be difficult for Norwegian politicians to conduct. Furthermore, Norwegian electricity consumers appear sensitive to the price of electricity. Cf. the comments made by Henriette Nesheim in the Ministry of Petroleum and Energy, about the "common perception that electrical power should be cheap and that Norway should be self-sufficient with this".

To further illustrate the legitimacy challenges in the Norwegian population, Wicken (2011) poses a compelling question: "is [electric] power a commercial product or a social infrastructure?" (p.128). He places the notion of electrical power in a historical context. That it has been a tradition in Norway with an easy access to cheap hydro power, both for industry and for private households. Moreover, Wicken points to a debate in the Norwegian magazine 'Teknisk Ukeblad' from 2011. In this debate, Norwegian labour politician Raymond Johansen claims that "We do not have any need for power in Norway" (Wicken, 2011, p. 129). A reply was written by a representative from Norwegian wind power association (Norwea), Øyvind Isachsen:

> Is there any need for salmon or oil in Norway? We could of course have closed the borders and eaten salmon five times a week and driven our cars on Norwegian oil and gas in 300 years, but no one demands that, says Isachsen, who believes that there is good money in exporting wind power (Teknisk Ukeblad, November 11, 2009).

The notion whether electricity is a tradable good or a part of a social infrastructure is central to the questions proposed in this thesis. Both the pace of the development of renewable energy in Norway and the question about an increased exchange capacity with

Europe can be assumed to be affected by this notion. This is consistent with the barriers found in the function about legitimation of such a development, as well as the statements made by Henriette Nesheim in the Ministry of Petroleum and Energy.

The consumers of electricity constitute a powerful group in the political landscape and represent a large share of voters. Hence, making political decisions that will increase the electricity prices are not favourable when the aim is to attract voters. For politicians in general there seem to be few incentives to approve major development projects of renewable energy in Norway. Hence, there is less legitimacy for Norwegian politicians to invest in energy production.

To summarise, seven plausible reasons for the lack of legitimacy are outlined: First, politicians do not have many incentives to plan many years further than four years ahead, which is their normal period in office. Second, as already pointed out, increased electricity prices will have negative consequences for energy-intensive industries, giving them less favourable conditions of competition. Third, a higher price of electricity is not popular amongst private consumers, which consists of voters. Fourth, environmental organisations and locals oppose any construction that can cause nature interventions. This causes demonstrations and protests, which is not desirable among politicians. Fifth, Norway already fulfils many of the renewable goals set in Europe. Norway has close to a 100% renewable electricity production and an increased development of interconnecting cables will first and foremost contribute to an increased share of renewables in Europe. Sixth, because of Norway's easy access to electricity and energy, Norway has fewer incentives to develop more renewable electricity than its European counterparts. Energy security is for any country one of the most pertinent foreign policy issues. Germany's building of renewable energy facilities does not only contribute to more renewable energy, but also to Germany's independence from importing fossil fuels from abroad. Furthermore, it also contributes to its ability to shut down nuclear power plants, which is an explicit policy goal (Pidd, H., 2011). These incentives do not exist for Norwegian politicians. Seventh, the Norwegian oil and gas industry is influential in the political landscape. Today, Norway is a major exporter of gas to the European continent. This is currently used for balancing the European electricity system. A notion of "Norway as Europe's green battery" can be seen as a threat to petroleum export industry due to the competition the electricity export possibly composes.

8. Concluding Remarks and Suggestions for Further Research

8.1 Conclusion and Policy Implications

This thesis has argued that there are barriers to the development of renewable energy technologies in Norway. It has applied the functional analysis developed by Bergek et al. (2008) to identify the hampering factors for renewable energy technology. Furthermore, the thesis has highlighted characteristics within the Norwegian innovation system, including the specific economic situation and, relative to European conditions, distinct energy system. A functional analysis has been applied in order to answer the first research question of this thesis: What hampers the development of renewable energy in Norway? The functionality of three functions has been evaluated; i) market formation; ii) resource mobilization; and iii) legitimation.

The main findings in this thesis are that there are hampering factors in the development of renewable energy technologies in Norway. It has been argued that there has been a lack of market incentives for developing additional renewable energy in Norway. The lack of incentives is closely connected to characteristics in the Norwegian NIS, in specific: the abundant energy resources; the neoclassical political economy approach; and the dominance of the petroleum sector. The incentives for investing in more electricity production in Norway have not been present in the last 30 years. The introduction of green certificates in 2012 is expected to provide incentives for developing renewable energy towards 2020. However, the demand for this electricity is uncertain.

The second research question in this thesis seeks to answer if it is possible for Norway to contribute to the transformation of the European electricity sector. Is an increased exchange of electricity between Norway and Europe feasible? As we have seen, there seems to be a discrepancy between German suggestions for exchange and current Norwegian plans and reports. However, there seems to be a consensus among the informants interviewed for this thesis, and the Thema report, that an increased exchange capacity is both needed and socio-economically beneficial. How extensive this development should be seems to depend upon some unanswered questions. First, there are uncertainties surrounding the effect on price mechanisms which an extensive development of grid and renewable energy production will trigger. Second, it is not clear who should pay for the interconnecting cables required for such a strategy. Third, legitimacy for more cables and high-voltage lines may be an issue. It is suitable to repeat the question posed by Wicken (2011): "is [electric] power a commercial product or a social infrastructure?" (p.128). Finally, what incentives does Norway have to transform the European electrical sector? For example, the informant from Energy Norway has requested more overarching framework conditions for the development of energy in Norway. This will allow investors to make long-term investments in renewable energy facilities. Uncertainties about the future price of electricity could be a possible deterrent for potential investors.

Overarching framework conditions and policies are key concepts for the development of renewable energy in Norway. This thesis has stressed that there is a logical flaw between the policies for renewable energy in Norway and the actual effect it has on the emissions of greenhouse gases. The fact that Norway has a fully renewable electricity sector makes the country different from many of its European counterparts. Moreover, the TGC and a potential increase of electricity may have unwanted consequences. It is important for decision-makers to consider the entire energy system and not only each policy isolated. Hence, a long-term system approach to a transition of the energy sector is appropriate.

Furthermore, the characteristic economic governance in Norway has implications on the pace of technological development. If it is assumed that technology specific policies are needed in order to deal with climate change, it could be argued that Norway does not provide this kind of policies. The way Norway deals with governmental investments, i.e. the short-term approach of Keynesianism and cost-benefit analysis, as well as the strict rules on how to spend the funds from the pension fund, can all be regarded as a neoclassical approach to technological change. Furthermore, the economic upturn can paradoxically lead to harder conditions for immature technology. The high-profit competing sectors and scarcity of competence lead to a lack of, and high prices on, competent labour. Besides, economic upturns lead to small investments made by the government, because the fear of an overheated economy.

An important aspect is that simply introducing electricity from renewable sources to the Norwegian market will in itself not reduce global carbon emissions. Based on the findings in this thesis, a logical line of reasoning can be formulated: The overall goal with climate policies in general is to reduce carbon emissions globally. A subordinate, but no less important goal could be to facilitate the development of renewable energy technologies. If Norway produces more electricity without phasing out electricity production based on fossil fuel, this would in itself not reduce carbon emissions. It will only produce more electricity in Norway (with a possible cost of interventions in nature). The development of renewable energy in Norway will contribute to a decrease in carbon emissions if it replaces the use of electricity/energy stemming from fossil resources. Based on the findings in this thesis there are three ways Norway could reduce carbon emissions: i) electrifying the offshore sector; ii) replace the transport sector's use of fossil fuels with e.g. electric or hydrogen cars; or iii) export renewable electricity to Europe. Hence, Europe could replace electricity based on fossil fuel with renewable energy form Norway. Furthermore, it could release an increased efficiency in renewable power plants due to the storage capacity of surplus electricity. This way, Norway could contribute to less emissions of carbon dioxide globally. Because, despite Norway's fortunate role of energy abundance, the world is in need of a transformation of its use and production of energy.

However, the European Union emission trading scheme will oppose this effect. If Norway exports renewable electricity to, for instance Denmark, Denmark can sell carbon emissions equivalent to the amount renewable electricity imported from Norway. If we assume that TGC has provided this extra energy the result does not look favourable. Not for Norway, and not for the environment. The total effect is that Denmark has been provided with a greater share of electricity paid by Norwegian electricity consumers. Furthermore, Denmark has gained on selling carbon emission. The total net emissions of greenhouse gases are the same, simply relocated from Denmark to another country.

This emphasises the need of overarching policies for the renewable energy system in Norway. System analyses that provide decision-makers with information to design technology-specific policies will expectantly be a more appropriate strategy than trusting that the market mechanisms will yield an optimal solution for the reduction of greenhouse gas emissions in Norway.

8.2 Suggestions for further research.

A better understanding of the system weaknesses of the Norwegian RET-TIS could be achieved through a more thorough TIS analysis. This could be done with a focus on all seven functions, as well as a more defined system framework. Such an analysis connected to the Norwegian NIS could be valuable in order to provide decision-makers with better information about the hampering factor in the Norwegian RET-TIS. It would have been particularly interesting to compare the Norwegian NIS and German NIS and try to identify dissimilarities that influence the significant difference between the performances in the development of renewable energy technologies.

A comprehensive analysis of price mechanisms connected to an extensive development of interconnecting cables could give a better answer to the second research question of this thesis. Furthermore, it could be appealing to look into alternative funding options of interconnecting cables. Is it a possibility that risks and costs of new cables are not born by Norwegian consumers and industry? More information about what effect this will have on the prices of electricity will also give politicians the possibility to better explain the positive aspects with an increased electricity exchange between Norway and Europe.

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Appendix: Interview guide

This is the interview guide which was used as a starting point at each interview. The interview guide was revised before each interview, and some of the interviews had different questions than other. It is important to notice that the interviews were semi-structured, that is the interviewees were controlling most of the conversations. However, I tried to guide them into the questions composed in this guide. Furthermore, their expertise provided me with much information about the system surrounding the Norwegian RET-TIS.

Research questions	***Interview questions***
Introduction questions. What is the current situation of renewable energy development and interconnecting cables?	- Green certificates? - Development since 1991? - Current situation: 1.5 GW with Germany? - What are the plans today?
• **Identifying system weaknesses in the Norwegian renewables TIS: the case of Norway as Europe's green battery.** a) Identification of the TIS functions in Norway's possibility to store energy for Germany. (cf. measuring functionality (Jacobsson and Bergek, 2011))	• Socio-economically positive? • What kinds of externalities are connected to such a development?
b) *And consequently:* What is hampering the process of building new renewables in Norway? (*Which functions are underdeveloped?)*	- What lacks in order to increase the development of renewable energy and grid? Technological barriers? - Environmental barriers - Economic barriers? - Political barriers?

c) *Hypothesis / proposition:* Norway lack the incentives to invest in new renewables, this could be due to the hydropower abundance and the profitable gas and oil export industry. **Lack of resource mobilisation?**	• Why do you think the investment in renewable energy is larger in Germany than in Norway? • Private investments? • Is there a lack of incentives in Norway? • Is the petroleum sector ”too profitable”? • Any further thoughts or comments regarding incentives?
d) *Hypothesis / proposition*: the function legitimisation is underdeveloped and need more attention to achieve / build the TIS. It does not seem legitimate to spend funds on a grid connection to Europe that will lead to higher electricity prices. **Legitimation**	- *What should and could be done?* - Which projects are today feasible? - Who should finance these investments? - Which institutions / networks are not interested in an increased development of grid and energy? - Your instituion’s role?